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CHARACTERIZATION OF TYPICAL PRODUCTION HOLE QUALITY AND INSPECTION TECHNIQUES

VOLUME II APPENDIXES B, C, D.

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This technical report has been reviewed and is approved for publication.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hole Quality	Tapering	Rifling
Hole Shape	Barrelling	Burrs
Perpendicularity	Ovality	Tears
Bellmouthing	Surface Finish	Laps
		Scratches

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Survey and on-site evaluation of fastener hole production processes were conducted to assess the characteristics of fastener holes as they are now being produced in industry. Details of a general written survey and the response by Industry are presented. Design of the experimental work being performed on the program is described. Major emphasis of the program was on personnel tooling process and cost control methods as characterized by the size, shape, surface finish, surface texture and alignment. A unique, (over)

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automated hole measurement system based on air gaging and analysis by programmable machine processing was used to characterize dimensional and shape parameters. An example of data acquisition and analysis is included.

Results show that design engineering tolerances are generally met by current process applications. Inspection methods are inadequate in identifying individual discrepancies in hole characteristics, but aid in process control to assure conformance to design criteria. Tooling, stack clamp up and hole to hole spacing were identified as the most dominant variables in current industry production.

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APPENDIX B

SURVEY OF CURRENT INDUSTRY PRACTICES

Prior to implementing the results of laboratory studies in firm contractual requirements, it was desirable to fully assess the baseline status of current production methods.

The objective of this survey was to provide one measure of the status of current production methods. The focus of our contract program was for straight fastener holes in the 3/16 to 5/8 inch diameter range as produced in aluminum alloy aircraft structures. We recognized that methods used and improvements suggested could be independent of material, hole size and requirements. The survey was therefore, oriented to hole production methods and was intended to characterize production methods.

Invited survey participants included both prime aircraft manufacturers and subcontract suppliers of aircraft components. It was recognized that the methods, specifications, etc., of prime manufacturers are imposed on subcontractors thus limiting the scope of methods variations. Individual

response from both prime contractors and subcontractors was desired to assess variations in requirements interpretation and reduction to a common shop practice, and to provide independent recommendations for improvement.

One hundred survey requests were sent out to manufacturers selected from industry contacts and from supplier listings in the <u>Thomas Register</u>. Participants were urged to answer all questions with recognition that some may not be applicable (N.A.) or may be sensitive (s) to a particular operation or organization. Participants were requested to note such questions and to answer all other as full as possible. Response by July 15, 1977 was requested.

This interim summary covers results of responses received as of October 28, 1977. Twenty-five completed surveys were returned and thirteen letters of regret were received. Additional responses are outstanding. Responses were segregated into the following groups for analysis:

Group A -- 9 responses - High performance aircraft design/manufacturers (Military Jet)

Group B -- 4 responses - Traditional aircraft design/manufacturers (Piston aircraft and light aircraft)

Group C -- 3 responses - Helicopter design/manufacturers

Group D -- 2 responses - Engine design/manufacturers

Group E -- 7 responses - Component Hardware Suppliers/Manufacturers

The survey questionnaire was divided into four categories and the results analyzed and divided as follows:

A. Design Factors Related to Hole Quality.

B. Production Factors Related to Hole Quality.

C. Inspection Factors Related to Hole Quality.

D. Cost Factors Related to Hole Quality.

ANALYSIS SUMMARY:

A. Design Factors Related to Hole Quality

1. Are fracture mechanics design principles used as a basis for design of fastener joints and in specification of hole quality characteristics?

   How?

   Response:

   Response was typically prime product oriented as follows:

   (a) Yes: Hi-performance aircraft contractors responded "yes" and also provided explanatory notes such as "used in primary structure and for identifying critical parts stress levels"; "required to meet certain life requirements"; "to meet the design--- of aircraft structures."

   (b) No: All traditional aircraft designers/manufacturers with no further notes.

   (c) No: All helicopter designer/manufacturers with no explanatory notes.

   (d) No: All component contractors - no additional notes.

   33% Yes responses

2. Does your design system classify holes in terms of criticality? (For example: "Critical -- A component for which a single failure would result in immediate loss of the aircraft"?

   (a) If yes, what classification system is used?

   Response:

   Yes: Hi-performance aircraft contractors and "hi-performance" engine manufacturers.

(a) Various answers were provided: Some identified company specifications, some identified criticality in terms of the joints and others in terms of bolts, taper lok fasteners, rivets and tolerances.

NOTE: Other contractors (see b, c and d per question #1) 87% No; 13% Yes

3. Are different tolerance/acceptance criteria specified for different hole classes?

(a) What differences are used?

Response:

Yes: Hi-performance aircraft contractors, "hi-performance" engine manufacturers and Helicopter designer/mfg.

(a) 100% inspection on .003" or less tolerance; type of material being assembled (steel, alum, titanium, etc.) has a bearing on inspection criterion. Also types of fastener (Taper-Lok, Hi-Shear).

No: Generally was the response on traditional aircraft and component contractors.

4. Do you use a preferred hole size range for critical holes?

(a) If yes, what is that range?

Response:

Yes: Hi-performance aircraft contractors and "hi-performance" engine manufacturers.

(a) Tolerance of .009" for body-round bolting on engines; structures people were .001" for close ream, .0015" interference and up to .003"/.004" (Class 1) dependent on type and quantity of fasteners.

NOTE: All other contractors (B, C, and E) responded, No.

5. Is your engineering dimensioning system in compliance with ANSI Y 14.5-1973?

   (a) Other?

   Response:

   Yes, 91% of all contractors responded affirmatively.

   (a) The only contractors (9%) responding "No" identified MIL-D-1000 as their control specification for dimensioning.

6. Do you interpret a tolerance of $\pm$ 0.001 as $\pm$ 0.0010?

   (a) Other?

   Response:

   Yes, 91% of all contractors responded affirmatively.

   (a) Of the (9%) responding "No" one contractor qualified his "No" with a note "Not usually, they report to the nearest .0005". The remainder offered no explanatory notes.

7. Do you specify hole production processes in your engineering system -- for example, "Drill and Ream?"

   (a) Do you specify the drilling process by tool identification? How?

   Response:

   No, 70%.

   Yes, 30%. Those who responded affirmatively provided notes such as "On drawings in some cases", "on line ream only".

   (a) Yes, specified in the planning sheets, not on the drawings.

8. Do you specify mandatory inspection of critical holes?

(a) How?

Response:

87%, Yes. All but one "hi-performance" aircraft manufacturer included in this percentage.

13%, No. One "hi-performance" aircraft manufacturer was included in this percentage but included a qualifying note as follows: "As in Question #2, holes not classified for criticality, but joints may be classified critical and Quality Assurance job sheets would direct inspection requirements.

(a) Drawing notes, Quality Assurance instructions, Engineering process specifications, work orders, and standard handbooks for inspection, define the inspections of critical holes.

9. Do you use a classification of characteristics in hole quality specification?

(a) If yes, does it include:

1 - Hole Size	5 - Surface condition - finish
2 - Roundness	6 - Surface Condition - Rifling, scratches, chatter marks, burrs
3 - Straightness	7 - Barrelling/Bellmouthing
4 - Alignment (Perpendicular, etc.)	

Please indicate typical tolerance range for each condition.

Response:

89%, Yes. This percentage represents all except one (1) of the contractors classified as hi-performance aircraft and hi-performance engine contractors.

NOTE: The overall aggregate percentage for this

question is as follows:

65%, Yes ----35%, No. The "No" percentage is eight (8) contractors, 50% of which (4 contractors) are component contractors.

(a) The contractors responding "Yes" to the question predominately identified all seven (7) characteristics in their specifications.

The tolerances were varied but are summarized as follows:

1 - Hole Size-----------varied .003" to .006" total
2 - Roundness-----------within diam. range of specific drawings
3 - Straightness--------Allow pins/rivets to be installed
4 - Alignment (perpendicular -- $\pm$ 1°; perpendicular within .002"
5 - Surface condition (finish)--63 to 125 RMS
6 - Surface condition (rifling, scratches, burrs)---Photographic standards, (most contractors, none allowed)
7 - Barreling/Bellmouthing--tolerance limits of specific drawings, where max/min diameters are specified.

10. Do you require recording of exact dimensions for critical holes or for critical interfaces?

(a) If yes, what dimensions?

Response:

88%, No. This percentage represents all except one (1) of the contractors classified as hi-performance aircraft manufacturers and hi-performance engine manufacturers. Only one (1) contractor in this category answered "Yes" to the question.

Overall aggregate percentage is:

82% No-------18%, Yes.

The total distribution answering "yes" are described in sub-section (a); four (4) contractors.

(a) The hi-performance aircraft manufacturing answering "Yes" provided the following qualifying statement. "Sometimes. Actual dimensions of critical interface/banking points to assist in further assembly operations."
One (1) - Traditional aircraft Mfg. failed to provide any explanatory note in response to (a).
One (1) - Helicopter Mfg. response to (a) was "diameter of hole and position."
One (1) - Component contractor answered "Yes" to the subject question but failed to provide narrative for (a).

11. Do you require of disassembly and deburring holes drilled through multiple-layer stacks?

(a) What methods are used for deburring?

Response:

89%, Yes. This percentage represents all but one (1) of the contractors classified as hi-performance aircraft manufacturers and hi-performance engine contractors.

Overall aggregate percentage is:

83%, Yes--------17%, No.

The total distribution answering "No" to the question were one (1) Hi-performance aircraft Mfg.; one (1) traditional aircraft Mfg.; one (1) helicopter Mfg. and one (1) component contractor.

(a) The method describing the deburring techniques were: countersink tool and/or flat abrasive, piloted countersinks and four fluted deburr tool, spring cutters, tumbling, 90^{o} edge cutters, drill press, files, etc.

12. Do you have a standard rework procedure specified for out-of-tolerance holes?

(a) Please describe.

Response:

88%, Yes. This percentage represents all but one (1) of the contractors classified as hi-performance aircraft manufacturers and hi-performance engine contractors.

(a) Generally the standard procedures for rework of out-of-tolerance holes are described in company Standard Repair Manuals, Eng. Repair and Specification Manuals, Overhaul and Repair Manuals, MRB Repair Instructions.

NOTE: Oversized holes are committed to Material Review Action which limits the prerogatives of the contractors.

B. Production Factors Related to Hole Quality

1. Do you use manufacturing processes to describe hole production methods and to control process parameters? Other/Comments.

   Response:

   100%, Yes. In all cases drilling by contractors is per controlled, written processes.

2. Are the same processes used to produce critical and non-critical holes? Please describe differences.

   Response:

   Basically, Yes. The difference lies in the method of producing the hole. Non-critical holes are drilled only. Critical holes employ drill, boring, reaming and honing to critical tolerances/finishes.

3. Are production operators trained and/or certified for production of critical holes? How? Please describe.

Response:

Yes, for contractors responsible for high performance aircraft and/or engines. Their programs train/certify individuals for specific skills (Taper-Lok, high strength materials, etc.). Traditional aircraft, helicopters and component contractors generally all have on-the-job training for operators/inspectors, but no formal certification on skill.

4. Are production drilling, equipment templates, etc., qualified for the process and hole quality required? How?

   Response:

   Yes, for contractors responsible for high performance aircraft and/or engines and component contractors. Through tool inspection ,certification before use, first piece inspection or destruction test.

   No, for traditional aircraft/helicopter contractors with no specific reasons identified.

5. Are hole production tools, i.e., twist drills, reamers, etc., inspected before use?

   (a) Is inspection documented?

   (b) Are actual characteristics recorded?

   Response:

   82% Yes. Inspected generally by machine operators prior to use. This percentage included all high performance aircraft and engine contractors.

   18% No. These were traditional aircraft/helicopter and component contractors.

   (a) Basically No. Inspections generally documented only on special tools and in problem areas.

   (b) Basically No. Same as above.

NOTE: Where (a) and (b) is providing documentation it is among the high performance aircraft/eng. contractors.

6. Are new drills, reamers, etc., inspected before being placed in stock?

   (a) Is inspection documented?

   (b) Are actual characteristics recorded?

   (c) Is trend monitoring and feed back used to assure that tools of the required (specified) quality are being delivered? Comments.

   Response:

   61% Yes. Percentage includes all high performance aircraft and engine contractors, but usually is for special drills, reamers and special geometry tooling.

   39% No. Percentage represents traditional aircraft, helicopter and some component contractors.

   (a) Basically No. Same as in question 5. Inspections are generally documented on special tools only.

   (b) Basically No. Same as (a) above.

   (c) Basically No. Trend data only when problems arise and troubleshooting.

7. What criteria are used in submitting tools for resharpening or replacement?

   (a) Are periodic inspection and recording of characteristics made after producing an predetermined number of holes?

   (b) Are quality characteristics of actual holes produced used as part of the basis for tool resharpening/replacement? How?

   Response:

Generally left to the judgement of the machine operator or technician. Quality of the holes monitored for signs of product degradation.

(a) Generally No. However, on long run jobs periodic checks are made.

(b) Yes, by operator judgement and work quality surveillance.

8. Are resharpened tools subjected to inspection before being placed in stock?

(a) Are actual characteristics recorded?

(b) How are the characteristics used? Comments.

Response:

74% Yes. Percentage includes all high performance aircraft and engine contractors.

(a) Basically No. Only recorded where special tools and geometry is involved.

(b) Characteristics used to evaluate acceptance of tool rework and specification compliance.

9. What factors do you consider to be most important in producing a close tolerance, drilled hole?

Comments:

Drill sharpness	Feed	Coolant	Drill Position
Drill point angle	Speed	Drill Start	Clamping of Material Stack
Drill flute angle	Torque	Drill Alignment	Operator Skill
Drill length	Pressure	Drill Removal	Other

Response:

Individual features varied among contractors; however, first rank with regard to importance in producing close tolerance holes are:

Drill physical geometric features of drill sharpness, point angle, flute angle, drill length.

Second ranking: mechanical features of alignment, clamping of material stack, position.

Third ranking: Operator skill, feed, speed, coolant.

10. In drilling close tolerance holes, the characteristics which are most difficult to control are: (Please indicate in ascending order from 1 to 8).

Hole size	Surface Condition Finish
Roundness	Surface Condition, Texture-Rifling, scratches, chatter marks, burrs
Alignment	Barrelling/Bellmouthing
	Other; Please explain

Response:

Characteristics varied among contractors according to the type of hardware representative of their prime product line.

(a) Among the high performance aircraft contractors the characteristics ranked:

1 - Size 2 - Surface Finish 3 - Roundness
4 - Surface Texture

(b) Among the traditional aircraft contractors the characteristics ranked:

1 - Size 2 - Surface Finish 3 - Roundness
4 - Surface Texture

(c) The high performance engine listing ranked the characteristics:

1 - Barrelling/Bellmouthing 2-Size 3-Surface Texture
4 - Surface Finish

(d) The helicopters were mixed but identified similar characteristics:

Size, Surface Finish, Surface Texture, Barrelling and Bellmouthing

11. Are criteria currently used in acceptance of close tolerance holes realistic?

(a) What characteristics (tolerances) could be relaxed? Please comment on rationale for relaxation.

(b) Would relaxation of criteria reduce production costs? How?

Response:

100% Yes. All concur that current close tolerance acceptance criterion is adequate.

(a) The most prolific characteristics selected for relaxation are relief in tolerances and surface finish of the completed hole.

(b) Reduction of inspection time, deburring and rework. All would be contributers to lower hole cost.

12. Are standard manufacturing processes used in reworking discrepant holes?

(a) How do the processes differ from original production methods?

Response:

83% Yes. The processes and tooling are basically the same as in production of original holes. This percentage includes <u>all</u> performance aircraft and engine

contractors.

(a) The processes vary little. The rework results are larger holes, bushed holes or sleeves in the affected parts. Generally controlled by MRB direction.

13. What improvements in hole production would you like to see to improve hole quality and/or reduced production costs?

Criteria	Fixtures	Temporary Clamping Devices	Inspection Equipment
Equipment	Tools	Cutting Fluids	Other

Response:

Individual features varied among contractors; however, the predominant candidates selected for improvement were:

First: Criteria; relax tolerance and finish requirements.

Second: Equipment; work on design improvements and better utility.

14. Please list **the distinct production methods** by **equipment** type, process, etc., which are in current use at your facility for producint straight holes in the 1/8 to 5/8 inch size range in aluminum alloy assemblies.

Please rank the methods according to usage and according to relative cost.

% of Production Cost

Response:

Answers varied according to product line and the percentage of usage was so diverse on equipment that they were not meaningful for comparison.

Example:

Hand drilling among high performance aircraft contractors varied from 8% to 50%.

Drill press varied from 4% to 33%.

Spacematic varied from 16% to 50%.

The equipment list identified the following:

Hand drill motors, drill press, spacematic power drills, drivematics, single point boring mills, N/C machines, overhead drills, track mounted drills, etc.

In the case of equipment, it is generally geographically situated to suit typical production line operations such as: machine shops,sub-assembly, major assembly, final assembly/test.

15. If the production process is not specified by engineering, how is the process selected?

Response:

Nearly unanimous response assigned process selection to the contractors manufacturing planning engineers (Production Engineering).

16. If deburring is not specified by engineering, is deburring performed?

(a) What rational is used to select a deburr process?

(b) Is deburring routinely performed on multiple layer stacks? Please comment.

Response:

91% Yes. Generally by invoking established workmanship standards.

(a) Hole utilization, general engineering notes (break sharp edges), joint criticality, company standard practices and in some cases special

metal removal procedures and limitations established by engineering.

(b) Yes, in 83% of responses. No, generally if stacks are drilled by semi-automatic or automatic riveting machines on aluminum stacks.

C. Inspection Factors Related to Hole Quality

1. Is your Quality Assurance/Inspection System designed to meet requirements for contracting with the governments?

If yes, which of the following documents are used?

Mil-I-45208A	NHB 5300.4 1 C	FAA Regulation, Vol. II Part 21
Mil-Q-9858A	NHB 5300.4 1 D	Other, Please specify
	NHB 5300.4 1 D1	

Response:

100% Yes. Specific contracts with governmental agencies invoke particular specifications; however, MIL-Q-9858A was in effect by all contractors 100%. The FAA Regulation, Vol. II, Part 21 and the NHB series documents were second and third most used by the response contractors.

2. Do your government contracts involve source inspection by a government agency?

(a) What agencies?

Response:

100% Yes. In this question, audit by Government Agency is considered "inspection."

(a) DCAS was identified in 75% of the total contractors responding to the survey.

NAVPRO, NASA, AFPRO, ARMY, NAVY, FAA, Defense Logistics and individual military installations were also identified.

3. If hole inspection methods are not called out on the engineering drawing or process specification, how is the method established?

Response:

82% identified their Quality Engineering or Quality Assurance Department as responsible for identifying the hole inspection method. The remainder identified experience and part tolerance which implied an inspection function and implemented per Quality Instructions in planning.

4. In fabrication of structures having a large number of similar holes, is sampling inspection utilized?

Yes No

(a) If Yes, is the sampling plan based on Mil-Standard 105D?

(b) Other?

Response:

78% Yes, Sampling permitted. Where response indicated no sampling was permitted a 100% inspection of critical holes is accomplished.

(a) MIL-STD-105D was the only sampling specification acknowledged by responding contractors.

(b) None identified.

4. a. What AQL is used?

How is the AQL requirement established?

Is sampling used in conjunction with (a) a tool inspection plan?

(b) trend data monitor based on hole quality characteristics in a sample run?

(c) Other?

Response:

A variety is used as controlled by the selections available via MIL-STD-105D.

Sampling when used is approximately 50/50 split between "a" "b" above.

4. b. If a hole is rejected in a sample lot, is additional inspection applied to that lot?

What is the basis for additional inspection?

Response:

Yes, additional inspections, generally 100% are performed with MIL-STD-105D as the control and directing document.

4. c. Are "go" - "no" gages used for inspection of close tolerance holes?

Are actual characteristics measured?

Please comment:

Response:

74%, Yes. However, "Go-No Go" gages are but one inspection tool from a variety employed to obtain actual measurement results.

Actual characteristics are measured using gaging tools other than "Go - No Go" plug gages to assess and inspect critical holes.

4. d. What measurement/assurance system is used to measure the following hole characteristics?

a. Hole size	c. Straightness	f. Surface condition/texture-rifling, scratches, chatter marks, burrs
b. Roundness	d. Alignment	
	e. Surface condition/finish	g. Barrelling/Bell-mouthing
		h. Other; Please comment

Response:

a. Dialboregage, air gages, Go-No Go gages, electronic gaging

b. Blade gage, dial bore gages, air gage, tally round gages, split ball and micrometer

c. Fixtures, indicators, pins, mating part, 3 axis measuring machine

d. Multiple pin gage, fastener pins, tool pins, surface table and height gage

e. Profilometer, surface indicator visual comparator, RMS gage

f. Optical comparator, visual, visual and magnification

g. Air gage, visual and plug, dial bore gage, ball gage and micrometer

h. No comments

Contractors were predominately consistent on inspection methods for the various hole characteristics.

5. a. What calibration/measurement accuracy ratio's are used for hole inspection tools?

What is the basis for recalibration?

a. Time (months)	c. Audit (basis)
b. Use (number of inspections)	d. Other; please comment

a. Since all contractors identified MIL-Q-9858A as applicable to their operations, MIL-C-45662 is implied by reference therein. Most contractors indicated a 10:1 accuracy for their hole inspection tooling.

The basis for recalibration was identified as follows:

First; a. Time (months)---the span time varied
Second; b. Use (Number of inspections)
Third; c. Audit (basis)---varied from a specific time period to "continuous"

6. Are inspectors qualified by performance for hole measurement?

(a) Are inspectors certified by training and examination for hole measurement?

Response:

74%, Yes on the basis of performance as stated in the question. 14% additional although answering in the negative qualified their "No" by stating that inspectors are trained for measurement of close tolerance holes and job rating is the criteria for qualification.

(a) Universally inspectors obtain astuteness and perfection in hole measurement via on-the-job training. Only in the high performance aircraft and engine contractors is certification rendered by "card."

7. Is the reliability of inspection measured by:

(a) Audit? (b) Double inspection? (c) Other?

Please comment.

Response:

86% identified (a; audit) as their primary reliability "tool" for measurement of inspection.

9% identified (b; double inspection).

5% identified (c; other). Physical product audit and customer feedback.

8. Are inspection processes used to describe and control inspection parameters? Other; please comment.

Response:

82%, Yes. Inspection processes in general are a universal descriptive "tool" for inspection purposes and although they carry a variety of titles they are synonymous in application.

9. What is the primary cause for rejection of holes at your facility?

Hole size	alignment	surface texture-scratches, rifling, etc.
Roundness	surface finish	barrelling/bellmouthing
Straightness		Other; please explain

Response:

100% identified "hole size" as the foremost cause for hole rejection. Roundness, bellmouthing and alignment were the next successive three causes for rejection.

10. Are reworked holes inspected on the same basis as original production? Yes No

(a) What are the differences?

Response:

83%, Yes. 17%, No, because holes were not inspected 100% originally.

(a) On reworked holes all receive 100% reinspection at completion of rework.

11. What improvements in hole inspection would you like to see to improve inspection precision and/or reduce inspection costs?

Response:

1 - Automated equipment to measure diameter perpendicularity, surface finish and other features automatically

2 - Incorporate digital readout on hole measuring equipment

3 - More wide spread use of air gage and electronic digital readout equipment to eliminate the human element in hole measurement

D. Cost Factors Related to Hole Quality

1. For production of close tolerance, straight holes in 1/4 inch thick aluminum (lots of 100 or more), what is the relative distribution of cost:

Response:

Response to this question was too broad and speciality oriented to extract meaningful data on the basis of commonality. For example, the tasks to be reported upon and the response among hi-performance aircraft and engine manufacturers are illustrated below. Identification of source is withheld. Figures reported are percentages.

Set Up	Drill	Ream	Counter Sink	Deburr	Tool Inspection	Set-Up Inspection	Hole Inspection	Tool Calibration	Documentation	Audit	Rework	Other; Please Specify
5	35	36	5	5	1	1	5	5	1		1	
2	80		10	2		5					1	
	*	= Highest cost	but no figures quoted		*							
	New product inadequate data for sample											
.6	65.6	7.7	13.1	3.9	Info not available						9.1	
19.8	8.0	17.8	19.8	6.8	1.0	2.6	17.0	2.6	2.6	NA	2.0	
30	20	0	15	20	2	0	6	1	5	1	0	
	No response by this contractor											

2. What is the average total cost of producing a close tolerance, straight hole in 1/4 inch thich aluminum? Manhours.

(a) Applicable to the ______production method?

Response:

As in Question #1 of this series, the responses were varied depending on the end product.

The example chosen to illustrate results are the same contractors from Question #1 and in identical

vertical order.

(a) All are applicable to full scale production.

0.06 manhour	Method not identified
0.062 manhour	Spacematic drilling
*	*Varies with application, requirements, location, etc.
See **	**.005 Drill; .003 Ream; CSK 001;
.026 manhour	Hand drilling method
.039 manhour	Drill press method
.04 manhour	Machines drill and ream
No response	

3. What costs are reduced for increased tolerance holes?

   Response:

   Generally all contractors acknowledged that <u>all</u> facets of cost would be reduced by some extent by opening the tolerance on holes. Prime areas of reduced cost: Inspection time and less inspections required. Reduction of rework required in drilling.
   Tooling cost reduced.
   Less disposition and repair activities..

4. What factors are major contributors to hole inspection costs? Please comment.

   Response:

   Among the hi-performance aircraft manufacturers and hi-performance engine contractors comments were:

   a - Certification and training of personnel and measuring gages

b - Close tolerance, rejection rates, and rework costs

c - Surface finish

d - Disassembly of drilled stack up

The above are fairly representative of all other contractor comments.

GENERAL:

Are you willing to furnish documentation relating to hole drilling processes, i.e., process specifications, drawings, process plans, inspection procedures, etc., to Martin Marietta Aerospace with an understanding that the confidential status of your company will be preserved and protected?

Comments:

Response:

The area of greatest interest (hi-performance aircraft contractors) responded favorably with regard to providing data per the above request. In general, the affirmative nature of the response was to provide info related to the study.

File 0

AUTOMATIC PROGRAM
LOAD AND START

APPENDIX C

DATA PROGRAM ANALYSIS

```
FILE      0
TYPE      0
USED      642
MAX       1500
```

Program	Explanation
0000 1	"1" is put in the X Register.
0001 IDENT 0002 ROLL↓ 0003 ROLL↓ 0004 ROLL↓ 0005 5	File 1 is identified and its file type is compared to the number 5 (type 5 is an empty file).
0006 IF X=Y 0007 GOTO L10	If they equal, (the file is empty) label 10 is addressed.
0009 FIX 0 0011 1 0012 7 0013 0 0014 #REGS 0015 0 0016 0 0017 ENTER↑ 0018 1 0019 LOAD	If they don't equal (the file is not empty), 170 memory registers are opened and file 1 data is loaded into memory.
0020 RCL R015	Register 15 (data lot) is recalled.
0022 IF 0 0023 GOTO L10	If it is zero, label 10 is addressed. If it is not zero, the program continues to step 25.

```
0025 PRNTα
0027 D
0028 A
0029 T
0030 A
0031
0032 L
0033 O
0034 T
0035 .
0036
0037 PRINT
0038 ENDα
```

The data lot (Register 15) is printed.

```
0039 SPACE
0040 PRNTα
0042 H
0043 O
0044 L
0045 E
0046
0047 N
0048 O
0049 .
0050 ?
0051 ENDα
0052 PRNTα
0054 I
0055 F
0056
0057 U
0058 N
0059 K
0060 N
0061 O
0062 W
0063 N
0064 ,
0065 LINE
0066 P
0067 R
0068 E
0069 S
0070 S
0071
0072 O
0073 ENDα
0074 STOP
0075 PRINT
0076 STO     R025
0078 SPACE
0079 SPACE
0080 GOTO    L01
```

The next hole number (keyboard entry) is requested from the operator.

If a number entry is made, it is stored in Register 25 and label 01 is addressed.

If the hole number is not known, a search routine is initiated by pressing the "0" key.

Pressing the "0" key addresses double label 0.

```
0082 LBL
---- 0
0084 LBL
---- 0
0086 CLX
0087 1
0088 STO      C
0089 RCL      C
0090 IDENT
0091 ROLL↓
0092 ROLL↓
0093 ROLL↓
0094 5
0095 IF X=Y
0096 GOTO     L04
0098 1
0099 IF X=Y
0100 GOTO     L10
0102 5
0103 STO+     C
0104 RCL      C
0105 3
0106 0
0107 IF X=Y
0108 GOTO     L04
0110 GOTO     0089
```

-Double Label 0-

The stack is cleared.

1 is stored in Register C.

(Step 089) Register C is recalled and the file with that number is identified. It's file type is compared to the number 5 (5 is an empty file).

If they equal, label 04 is addressed.

If they don't equal, the file type is compared to the number 1 (1 is a secured program file).

If they equal, lable 10 is addressed.

If they don't equal, 5 is added to the number in Register C.

Register C is recalled and is compared to the number 30 (30 is the largest amount of files used per set of holes).

If they equal, label 04 is addressed.

If they don't equal, the problem jumps back to step 89.

```
0112 LBL
---- 04
0114 RCL      C
0115 5
0116 -
0117 STO      C
0118 1
0119 STO+     C
0120 RCL      C
0121 IDENT
0122 ROLL↓
0123 ROLL↓
0124 ROLL↓
0125 5
0126 IF X=Y
0127 GOTO     L05
0129 GOTO     0118
```

-Label 04-

Label 04 (steps 0112 through 0129) continues to search for an empty file by step increments of "1".

A "5" is subtracted from Register C.

A "1" is added to the number in Register C and that file type is identified.

The file type is compared to the number 5 (empty file code).

If the file is not empty (file code not equal to 5), the program jumps back to step 0118, adds 1 to the number in Register C and continues until an empty file is located.

If the file is empty (file code = 5) label 05 is addressed.

0131 LBL			**Label 05**
---- 05			
0133 RCL	C		Label 05, Register C is recalled, "1" is subtracted from this number and it is restored in Register C. The X register is cleared.
0134 1			
0135 STO-	C		
0136 CLX			
0137 FIX	0		
0139 1			The file (Register C) is loaded.
0140 7			
0141 0			Register 015 is recalled (Lot number).
0142 #REGS			
0143 0			If register 015 contains a zero, Label 10 is addressed. This is a routine to protect file "0" from accidental erasure. If a blank tape is put into the computer and "0" is entered, this program finds File 1 to be the first empty data file. If "1" is subtracted from 1, file 0 will be reloaded. Label 10 will be addressed.
0144 0			
0145 ENTER↑			
0146 RCL	C		
0147 LOAD			
0148 FIX	0		
0150 RCL	R015		
0152 IF 0			
0153 GOTO	L10		If Register 015 is not zero, the program continues.

Step	Instruction	Operand	Comment
0155	PRNTα		
0157	D		
0158	A		The Data Lot number (Register 15) is printed.
0159	T		
0160	A		
0161			
0162	L		
0163	O		
0164	T		
0165	.		
0166			
0167	PRINT		
0168	ENDα		
0169	RCL	R025	
0171	1		A "1" is added to the number in Register 025 and stored in Register 025.
0172	+		
0173	STO	R025	
0175	PRNTα		
0177	N		
0178	E		
0179	X		
0180	T		
0181			
0182	H		The next hole number (Register 025) is printed.
0183	O		
0184	L		
0185	E		
0186			
0187	PRINT		
0188	ENDα		
0189	SPACE		
0190	PRNTα		
0192	H		
0193	O		
0194	L		
0195	E		
0196			Keyboard entry of the next hole number to be addressed is requested from the operator.
0197	N		
0198	O		
0199	.		
0200	?		
0201	ENDα		
0202	STOP		
0203	PRINT		
0204	STO	R025	On keyboard entry of hole number, the program continues.
0206	SPACE		
0207	SPACE		
0208	GOTO	L01	Label 01 is addressed.

-Label 01-

```
0210 LBL
---- 01
0212 RCL     R016
0214 PRNTα
0216 D
0217 A
0218 T
0219 E
0220
0221 PRINT
0222 ENDα
0223 RCL     R017
0225 PRNTα
0227 D
0228 A
0229 T
0230 A
0231
0232 S
0233 O
0234 U
0235 R
0236 C
0237 E
0238
0239 PRINT
0240 ENDα
0241 RCL     R015
0243 PRNTα
0245 D
0246 A
0247 T
0248 A
0249
0250 L
0251 O
0252 T
0253
0254 PRINT
0255 ENDα
0256 RCL     R025
0258 PRNTα
0260 H
0261 O
0262 L
0263 E
0264
0265 N
0266 O
0267 .
0268
0269 PRINT
0270 ENDα
```

Register 016 (date of data entry) is recalled and printed.

Register 017 (data source) is recalled and printed.

Register 015 (Data Lot) is recalled and printed.

Register 025 (Hole Number) is recalled and printed.

File 0

```
0271 FIX     4
0273 RCL     R006
0275 PRNTα
0277 A
0278 M
0279 P
0280 L
0281 I
0282 E
0283 R
0284 ENDα
0285 PRNTα
0287 R
0288 A
0289 N
0290 G
0291 E
0292 =
0293
0294 PRINT
0295 ENDα
0296 PRNTα
0298 D
0299 E
0300 S
0301 I
0302 G
0303 N
0304
0305 T
0306 O
0307 L
0308 E
0309 R
0310 A
0311 N
0312 C
0313 E
0314 ENDα
0315 FIX     6
0317 RCL     R011
0319 PRNTα
0321
0322 L
0323 .
0324 L
0325 .
0326 =
0327 PRINT
0328 ENDα
0329 RCL     R012
0331 PRNTα
0333
0334 U
0335 .
0336 L
0337 .
0338 =
0339 PRINT
0340 ENDα
```

Register 006 (Amplifier Range) is recalled and printed.

"Design Tolerance" is printed.

Register 011 (Lower Limit) is recalled and printed.

Register 012 (Upper Limit) is recalled and printed.

File 0

```
0341 SPACE
0342 PRNTα
0344 G
0345 A
0346 G
0347 E
0348
0349 S
0350 E
0351 T
0352 -
0353 U
0354 P
0355 *
```

"Gage Set - Up * * * * *" is printed.

```
0356 *
0357 *
0358 *
0359 *
0360 ENDα
0361 PRNTα
0363
0364 N
0365 O
0366 M
0367 I
0368 N
0369 A
0370 L
0371
```

Register 030 (Nominal Size) is recalled and printed.

```
0372 S
0373 I
0374 Z
0375 E
0376 =
0377 ENDα
0378 RCL      R030
0380 PRINT
0381 RCL      R029
0383 PRNTα
0385
0386 L
0387 .
0388 L
0389 .
0390 =
```

Register 029 (Lower Limit)is recalled and printed.

```
0391
0392 PRINT
0393 ENDα
0394 RCL      R031
0396 PRNTα
0398
0399 U
0400 .
0401 L
0402 .
0403 =
```

Register 031 (Upper Limit)is Recalled and printed.

```
0404
0405 PRINT
0406 ENDα
```

```
0407 SPACE
0408 PRNTα
0410 T
0411 O
0412                                   File 0
0413 E
0414 N
0415 D
0416
0417 D
0418 A
0419 T
0420 A
0421 ,
0422 LINE
0423 P
0424 R
0425 E
0426 S
0427 S
0428                     "To End Data, Press Stop / A"
0429 S
0430 T
0431 O
0432 P
0433 /
0434 A
0435 ENDα
0436 PRNTα
0438 T
0439 O
0440
0441 C
0442 O
0443 R
0444 R
0445 E
0446 C
0447 T
0448                     "To Correct Data, Press Stop / B"
0449 D                    is printed.
0450 A
0451 T
0452 A
0453 ,
0454 P
0455 R
0456 E
0457 S
0458 S
0459
0460 S
0461 T
0462 O
0463 P
0464 /
0465 B
0466 ENDα
0467 RCL      R005       Register 005 is recalled and stored
0469 STO      J          in Register J.
0470 CLEAR
0471 3                   File -3 is loaded into the computer.
0472 +⇄-
0473 LD&GO
```

```
0474 LBL
---- 10
0476 PRNTα
0478
0479
0480
0481
0482 M
0483 A
0484 R
0485 T
0486 I
0487 N
0488 LINE
0489
0490
0491
0492 M
0493 A
0494 R
0495 I
0496 E
0497 T
0498 T
0499 A
0500 LINE
0501
0502
0503
0504 A
0505 E
0506 R
0507 O
0508 S
0509 P
0510 A
0511 C
0512 E
0513 LINE
0514 D
0515 E
0516 N
0517 V
0518 E
0519 R
0520
0521 D
0522 I
0523 V
0524 I
0525 S
0526 I
0527 O
0528 N
0529 LINE
```

Label 10 prints a header message on the top of the tape to show that this is the beginning of the hole measuring procedures. The message is as noted below:

```
      MARTIN
     MARIETTA
     AEROSPACE
  DENVER DIVISION
    PROJECT 1000

  PRESS EITHER KEY
   A OR B.
  A= MANUAL
    DATA ENTRY.
  B= INTERFACE
    DATA ENTRY.
```

Choice A loads file -0

Choice B loads file -1

File 0

```
0530
0531
0532 P
0533 R
0534 O
0535 J
0536 E
0537 C
0538 T
0539
0540 1
0541 0
0542 0
0543 0
0544 LINE
0545 LINE
0546 P
0547 R
0548 E
0549 S
0550 S
0551
0552 E
0553 I
0554 T
0555 H
0556 E
0557 R
0558
0559 K
0560 E
0561 Y
0562
0563 A
0564
0565 O
0566 R
0567
0568 B
0569 .
0570 LINE
0571 [illegible]
0572
0573
0574 M
0575 A
0576 N
0577 U
0578 A
0579 L
0580 LINE
0581
0582
0583 D
0584 A
0585 T
0586 A
0587
0588 E
0589 N
0590 T
0591 R
0592 Y
0593 .
0594 LINE
0595 B
0596 =
0597
0598 I
0599 N
0600 T
0601 E
0602 R
0603 F
0604 A
0605 C
0606 E
0607 LINE
0608
0609
0610 D
0611 A
0612 T
0613 A
0614
0615 E
0616 N
0617 T
0618 R
0619 Y
0620 .
0621 ENDα
0622 STOP
0623 SPACE
0624 SPACE
0625 LBL
---- A
0627 LBL
---- A
0629 CLEAR
0630 0
0631 +≑-
0632 LD&GO
0633 LBL
---- B
0635 LBL
---- B
0637 CLEAR
0638 1
0639 +≑-
0640 LD&GO
0641 END
```

Choice A loads File -0

Choice B loads File -1

```
FILE    -1
TYPE     0
USED     415
MAX      1000
```

File 0

```
0000 NOP
0001 NOP
0002 NOP
0003 NOP
0004 NOP
0005 NOP
0006 FIX     0
0008 NOP
0009 1
0010 7
0011 0
0012 #REGS
```

In File -1, the first 170 registers are opened for the storage of data.

```
0013 NOP
0014 PRNTα
0016 I
0017 N
0018 T
0019 E
0020 R
0021 F
0022 A
0023 C
0024 E
0025
0026 D
0027 A
0028 T
0029 A
0030 LINE
0031 E
0032 N
0033 T
0034 R
0035 Y
0036
0037 S
0038 E
0039 L
0040 E
0041 C
0042 T
0043 E
0044 D
```

The message "Interface Data Entry Selected" is printed on the tape.

```
0045 LINE
0046 D
0047 A
0048 T
0049 E
0050
0051 ?
0052 ENDα
```

The Date is requested.

```
0053 STOP
0054 PRINT
0055 STO     R016
```

The date is entered from the keyboard and stored in Register 016.

File 0

```
0057 PRNTα
0059 D
0060 A
0061 T
0062 A
0063
0064 S
0065 O
0066 U
0067 R
0068 C
0069 E
0070
0071 ?
0072 ENDα
0073 STOP
0074 PRINT
0075 STO      R017
```

Next, the program requests entry of the data source. The source is enered from the keyboard and is stored in Register 017.

```
0077 PRNTα
0079 D
0080 A
0081 T
0082 A
0083
0084 L
0085 O
0086 T
0087
0088 ?
0089 ENDα
0090 STOP
0091 PRINT
0092 STO      R015
```

The data lot is requested. The data lot is entered from the keyboard and is stored in Register 015.

```
0094 0
0095 PRNTα
0097 H
0098 O
0099 L
0100 E
0101
0102 N
0103 O
0104 .
0105
0106 ?
0107 ENDα
0108 STOP
0109 PRINT
0110 IF 0
0111 GOTO     0095
0113 IF -
0114 GOTO     0095
0116 STO      R025
0118 NOP
0119 CLRA→J
```

The Hole Number is requested. The Hole Number is entered from the keyboard and stored in Register 025. The Hole Number must not be a negative number or a zero otherwise it will recycle to step 0095 and ask for the Hole Number again. Registers A through J are cleared.

```
0120 1
0121 2
0122 0
0123 0
0124 STO      B
0125 1
0126 1
0127 6
0128 0
0129 STO      C
0130 FIX      4
0132 CLEAR
```

1200 is stored in Register B
1160 is stored in Register C. These are scaling factor constants.
A Fix 4 is inserted to fix the data to 4 significant figures.
The stack is cleared.

- Label 10 -

```
0133 LBL
---- 10
0135 PRNTα
0137 LINE
0138
0139
0140 E
0141 N
0142 T
0143 E
0144 R
0145
0146 R
0147 A
0148 N
0149 G
0150 E
0151 LINE
0152
0153
0154 A
0155 S
0156
0157 S
0158 H
0159 O
0160 W
0161 N
0162
0163 O
0164 N
0165 LINE
0166 P
0167 R
0168 E
0169 T
0170 E
0171 C
0172
0173 A
0174 M
0175 P
0176 L
0177 I
0178 F
0179 I
0180 E
0181 R
0182 LINE
0183 LINE
0184 ENDα
0185 STOP
0186 STO     A
0187 LOG
0188 IF +
0189 GOTO    L00
0191 +⇄-
0192 2
0193 *
0194 INT
```

This label prints the message "Enter Range As Shown on Pretec Amplifier." This range number is stored in Register A and the Base 10 log of the number is taken.

If the log is a positive number, Label 00 is addressed.

If the log is a negative number, it is inverted to a positive number, multiplied by 2 and the integer of the number is taken. The message "Inches Chosen" is printed.

```
0195 PRNTα
0197 I
0198 N
0199 C
0200 H
0201 E
0202 S
0203
0204 C
0205 H
0206 O
0207 S
0208 E
0209 N
0210 .
0211 ENDα
0212 GOSUB   LX
0213 RCL     J
0214 STO     R005
```

This number is now the address number for a "Go Subroutine." It is always between 3 and 8 depending on the range chosen.

Register J is recalled and stored in Register 05.

```
0216 LBL
---- 99
0218 RCL     A
0219 STO     R006
```

Label 99 recalls Register A (Amplifier Range) and stores it in Register 006

```
0221 PRNTα
0223 R
0224 A
0225 N
0226 G
0227 E
0228 =
0229 PRINT
```

The message "Range =" is printed along with the range chosen.

```
0230 LINE
0231 LINE
0232 I
0233 F
0234
0235 O
0236 K
0237 ,
0238
0239 P
0240 R
0241 E
0242 S
0243 S
0244 LINE
0245 R
0246 U
0247 N
0248 /
0249 S
0250 T
0251 O
0252 P
0253 ,
0254
0255 E
0256 L
0257 S
0258 E
0259 LINE
0260 P
0261 R
0262 E
0263 S
0264 S
0265
0266 O
0267 LINE
0268 LINE
0269 ENDα
0270 STOP
```

The message "If OK, press Run/Stop, else press 0" is printed.

If "0" is chosen, Label 10 is addressed and it repeats the amplifier range input.

```
0271 CLEAR
0272 2
0273 +÷-
0274 LD&GO
0275 LBL
---- 0
0277 LBL
---- 0
0279 GOTO    L10
```

If Run/Stop is chosen the computer loads in File -2.

```
0281 LBL
---- 03
0283 FIX    4
0285 4
0286 STO    R001
0288 RCL    A
0289 RCL    B
0290 ÷
0291 STO    J
0292 RETURN
0293 LBL
---- 04
0295 FIX    4
0297 4
0298 STO    R001
0300 RCL    A
0301 RCL    C
0302 ÷
0303 STO    J
0304 RETURN
0305 LBL
---- 05
0307 FIX    5
0309 5
0310 STO    R001
0312 RCL    A
0313 RCL    B
0314 ÷
0315 STO    J
0316 RETURN
0317 LBL
---- 06
0319 FIX    5
0321 5
0322 STO    R001
0324 RCL    A
0325 RCL    C
0326 ÷
0327 STO    J
0328 RETURN
0329 LBL
---- 07
0331 FIX    6
0333 6
0334 STO    R018
0336 RCL    A
0337 RCL    B
0338 ÷
0339 STO    J
0340 RETURN
0341 LBL
---- 08
0343 FIX    6
0345 6
0346 STO    R001
0348 RCL    A
0349 RCL    C
0350 ÷
0351 STO    J
0352 RETURN
```

Labels 3 and 4 store a "4" in Register 001.

Labels 5 and 6 store a "5" in R001.

Labels 7 and 8 store a "6" in R001.

Next labels 3,5 and 7 recall Registers A and B and divide Register B (1200) into Register A.

This number is now stored in Register J.

Labels 4,6,8 recall registers A and C and divide Register C (1160) into Register A.

This number is now stored in Register J.

The program returns to Step 0213. Next Register J is recalled and stored in Register 005. Label 99 is then addressed

```
0353 LBL
---- 00
0355 PRNTα
0357 I
0358 N
0359 V
0360 A
0361 L
0362 I
0363 D
0364
0365 E
0366 N
0367 T
0368 R
0369 Y
0370 LINα
0371 M
0372 M
0373
0374 R
0375 A
0376 N
0377 G
0378 E
0379
0380 C
0381 H
0382 O
0383 S
0384 E
0385 N
0386 LINE
0387 LINE
0388 E
0389 N
0390 T
0391 E
0392 R
0393 LINE
0394 C
0395 O
0396 R
0397 R
0398 E
0399 C
0400 T
0401
0402 R
0403 A
0404 N
0405 G
0406 E
0407 ENDα
0408 LBL
---- O
0410 LBL
---- O
0412 GOTO   L10
0414 END
```

Label 00 is an error message that is printed when a number greater than 1 is entered for the amplifier range.

FILE -2

DATA TAPE FILE

Loaded from File -1

```
FILE    -2
TYPE     0
USED     260
MAX      1000

0000 NOP
0001 NOP
0002 NOP
0003 FIX      6
0005 PRNTα
0007 D
0008 E
0009 S
0010 I
0011 G
0012 N
0013
0014 T
0015 O
0016 L
0017 E
0018 R
0019 A
0020 N
0021 C
0022 E
0023 ENDα
```

"Design Tolerance" is printed.

```
0024 PRNTα
0026
0027 L
0028 .
0029 L
0030 .
0031 =
0032 ?
0033 ENDα
0034 STOP
0035 PRINT
0036 STO      R011
```

The Program asks for the Lower Limit Value. The Lower Limit is entered from the keyboard, is stored in Register 011 and printed on the tape.

```
0039 PRNTα
0040
0041 U
0042 .
0043 L
0044 .
0045 =
0046 ?
0047 ENDα
0048 STOP
0049 PRINT
0050 STO      R012
```

The Program asks for the Upper Limit Value. The Upper Limit is entered from the Keyboard, stored in Register 012, and is printed on the tape.

```
0052 PRNTα
0054 G
0055 A
0056 G
0057 E
0058
0059 S
0060 E
0061 T
0062 -
0063 U
0064 P
0065 *
0066 *
0067 *
0068 *
0069 *
0070 ENDα
```

"Gage Set Up" is printed.

```
0071 PRNTα
0073
0074 N
0075 O
0076 M
0077 I
0078 N
0079 A
0080 L
0081
0082 S
0083 I
0084 Z
0085 E
0086 =
0087 ?
0088 ENDα
0089 STOP
0090 PRINT
0091 STO      R030
```

The Nominal Size is requested. The Nominal Size is entered from the keyboard, stored in Register 030 and printed on the tape.

```
0093 PRNTα
0095
0096 L
0097 O
0098 W
0099 E
0100 R
0101
0102 L
0103 I
0104 M
0105 I
0106 T
0107 =
0108 ?
0109 ENDα
0110 STOP
0111 PRINT
0112 STO      R029
```

The Lower Limit value is then requested and when entered from the keyboard, it is stored in Register 029 and printed on the tape.

File -2

```
0114 PRNTα
0116
0117 U
0118 P
0119 P
0120 E
0121 R
0122
0123 L
0124 I
0125 M
0126 I
0127 T
0128 =
0129 ?
0130 ENDα
0131 STOP
0132 PRINT
0133 STO      R031
```

The Upper Limit Value is then requested. The Upper Limit is entered from the Keyboard, is stored in Register 031 and is printed on the tape.

```
0135 PRNTα
0137 LINE
0138 I
0139 F
0140
0141 O
0142 K
0143 ,
0144
0145 P
0146 R
0147 E
0148 S
0149 S
0150 LINE
0151 R
0152 U
0153 N
0154 /
0155 S
0156 T
0157 O
0158 P
0159 ,
0160
0161 E
0162 L
0163 S
0164 E
0165 LINE
0166 P
0167 R
0168 E
0169 S
0170 S
0171
0172 O
0173 ENDα
```

"If Ok, Press Run/Stop, else Press 0" is printed.

```
0174 STOP
0175 GOTO     L20
```

Label 20 is addressed if Run/Stop is pressed.

File -2

```
0177 LBL
---- 0
0179 LBL
---- 0
0181 GOTO   0000
```

If "0" was pressed, Double Label 0 is addressed and program returns to Step 0000 and starts over again.

- Label 20 -

If Run/Stop was pressed, label 20 is addressed and

"To End Data Entry, Press Stop/A

To Correct Data Entry, Press Stop/B"

is printed on tape.

```
0183 LBL
---- 20
0185 PRNTα
0187 T
0188 O
0189
0190 E
0191 N
0192 D
0193
0194 D
0195 A
0196 T
0197 A
0198 LINE
0199 E
0200 N
0201 T
0202 R
0203 Y
0204 ,
0205
0206 P
0207 R
0208 E
0209 S
0210 S
0211 LINE
0212 S
0213 T
0214 O
0215 P
0216 /
0217 A
0218 LINE
0219 T
0220 O
0221
0222 C
0223 O
0224 R
0225 R
0226 E
0227 C
0228 T
0229
0230 D
0231 A
0232 T
0233 A
0234 LINE
0235 E
0236 N
0237 T
0238 R
0239 Y
0240 ,
0241
0242 P
0243 R
0244 E
0245 S
0246 S
0247 LINE
0248 S
0249 T
0250 O
0251 P
0252 /
0253 B
0254 ENDα
0255 CLEAR
0256 3
0257 +≑-
0258 LD&GO
0259 END
```

File -3 is then loaded into the computer

File -3

```
FILE   -3
TYPE    0
USED    343
MAX     1000

0000 NOP
0001 NOP
0002 NOP
0003 NOP
0004 NOP
0005 NOP
0006 NOP
0007 NOP
0008 NOP
0009 1
0010 7
0011 0
0012 #REGS
0013 FIX     6
0015 PRNTα
0017 E
0018 N
0019 T
0020
0021
0022
0023 D
0024 A
0025 T
0026 A
0027 LINE
0028 *
0029
0030 *
0031
0032 *
0033
0034 )
0035
0036 *
0037
0038 )
0039
0040 *
0041
0042 )
0043
0044 ENDα
0045 4
0046 0
0047 STO     G
0048 GOTO    L88
0050 NOP
0051 NOP
```

Steps 0009 through 0012 open up 170 Registers for memory storage. The calculator is set to display data to six significant digits.

Steps 0015 through 0044 print the message:

"Enter Data"

* * * * * * * *

The Constant "40" is stored in Register G.

Label 88 is addressed.

LABEL 88

Register H is recalled and is placed in the X Register of the stack. At the beginning of the program, Register H is empty and a zero will be placed in the X Register. This number is also displayed digit form on the HP 9815 Computer. Register H functions as a counter for the number of data measurements taken.

"Stat 4" Step is requested. This Step Checks the peripheral to see if the foot-switch has been depressed. If it has, data is ready to be stored into the computer and sub label G is addressed.

If the footswitch has not yet been depressed, Register H is recalled again and displayed.

Label 88 is again addressed. This label will continue displaying the current number of entries taken until the foot-switch is depressed.

```
0052 LBL
---- 88
0054 RCL     H
0055 CALL    4G
0057 IF +
0058 GOSUB   G
0060 RCL     H
0061 PAUSE
0062 GOTO    L88
0064 STOP
```

File -3

LABEL G

```
0065 LBL
---- G
0067 RCL    G
0068 1
0069 +
0070 STO    G
0071 1
0072 STO    A
0073 2
0074 5
0075 STO    F
0076 CLEAR
0077 2
0078 ENTER↑
0079 CALL   4K
0081 CALL   4A
0083 FOR    A→F
0084 NEXT   A
0085 CLEAR
0086 CALL   4K
0088 CALL   4A
0090 RCL    J
0091 *
0092 RCL    R030
0094 +
0095 STO I  G
0097 PRINT
```

Register G is recalled, "1" is added to it and restored in Register G.

An A -- F "For Next" loop is set up storing "1" in Register A and "25" in Register F.

The Register Stack is cleared and a "2" is put into the X and Y Register. A 2 in the Y Register of the stack identifies the handshake between the computer and the peripheral as a pulsed handshake (Mode 2). This handshake is repeated 25 times during the "For Next" loop. This gives sufficient time to complete transfer of data from the peripheral to the computer.

When the Program completes the loop, the stack is cleared and another handshake is completed. This time a handshake mode 0 is performed and the data that is latched by the computer and stored in the X Register is multiplied by the contents of Register J (Interface-Amplifier Scaling Factor) and is added to Register 30 (Nominal Size).

The product is stored in the Register number indicated by Register G (starting with Register 41 and continuing in unit intervals until there is no more data). The data is printed on the tape.

File -3

```
0120 LBL
---- B
0122 LBL
---- B
0124 PRNTα
0126 E
0127 R
0128 R
0129 O
0130 R
0131 *
0132 L
0133 A
0134 S
0135 T
0136
0137 E
0138 N
0139 T
0140 R
0141 Y
0142
0143 D
0144 E
0145 L
0146 E
0147 T
0148 E
0149 D
0150 LINE
0151
0152
0153
0154
0155 N
0156 E
0157 W
0158
0159 E
0160 N
0161 T
0162 R
0163 Y
0164 LINE
0165 V
0166
0167 V
0168
0169 V
0170
0171 V
0172
0173 V
0174
0175 V
0176
0177 V
0178
0179 V
0180
0181 ENDα
```

Double Label B is addressed when a correction is to be made. It prints the statement:

"Error * Last Entry Deleted

New Entry V V V V V V V V"

and continues.

```
0246 RCL     G
```

Register G is recalled. 41 is subtracted from it.

```
0247 4
0248 1
0249 -
0250 PRNTα
0252 PRINT
0253
0254 D
0255 A
0256 T
0257 A
0258
```

This value is the number of data entries taken and is printed on the tape as such.

Register 025 is recalled (Hole Number) to identify the file in which the data is stored. (Files 1 through 29). The message "Data Recorded in File" is printed with the number in Register 025.

```
0259 E
0260 N
0261 T
0262 R
0263 I
0264 E
0265 S
0266 ENDα
0267 RCL     R025
0269 PRNTα
0271 D
0272 A
0273 T
0274 A
0275
0276 R
0277 E
0278 C
0279 O
0280 R
0281 D
0282 E
0283 D
0284 LINE
0285 I
0286 N
0287
0288 F
0289 I
0290 L
0291 E
0292
0293 PRINT
0294
0295 ENDα
0296 NOP
0297 NOP
0298 NOP
0299 RCL     R025
```

Register 025 is recalled, "1" is added to it and it is restored in Register 025.

```
0301 1
0302 +
0303 STO     R025
```

FILE -3

```
0305 PRNTα
0307 N
0308 E
0309 X
0310 T
0311
0312 H
0313 O
0314 L
0315 E
0316
0317 PRINT
```

A "Next Hole" message is printed on the tape with the new number in Register 025.

```
0318 ENDα
0319 CLEAR
0320 SPACE
0321 SPACE
0322 SPACE
0323 SPACE
0324 RCL      R025
0326 PRNTα
0328 H
0329 O
0330 L
0331 E
0332
0333 N
0334 O
0335 .
0336 PRINT
0337 ENDα
```

The stack is cleared and Register 025 is recalled. The message "Hole Number" is printed with the number in Register 025.

```
0338 0
0339 STO      H
0340 GOTO     0000
0342 END
```

A zero is stored in H (Data Entry Counter), the program jumps back to step 0000 and the data entry process is repeated.

File -8

```
FILE   -8
TYPE    0
USED    338
MAX     1000

0000 NOP
0001 1
0002 7
0003 0
0004 #REGS
```

170 Registers are opened for storage.

```
0005 RCL      R025
0007 0
0008 IF X<Y
0009 GOTO     0086
0011 IF 0
0012 PRNTα
0014 I
0015 N
0016 S
0017 E
0018 R
0019 T
0020
0021 D
0022 A
0023 T
0024 A
0025
0026 T
0027 A
0028 P
0029 E
0030 ENDα
0031 STOP
```

The message "Insert Data Tape" is printed.

When Data Tape is inserted, Run/Stop is pressed to continue.

```
0032 SPACE
0033 FIX      0
0035 PRNTα
0037 H
0038 O
0039 L
0040 E
0041
0042 N
0043 O
0044 .
0045
0046 ?
0047 ENDα
0048 STOP
```

The Hole Number is requested .

```
0049 PRINT
0050 STO      R025
```

It is stored in Register 025.

```
0052 SPACE
0053 CLX
0054 FIX     0
0056 1
0057 7
0058 0
0059 #REGS
0060 0
0061 0
0062 ENTER↑
0063 RCL     R025
0065 LOAD
0066 PRNTα
0068 I
0069 N
0070 S
0071 E
0072 R
0073 T
0074
0075 P
0076 R
0077 G
0078 M
0079
0080 T
0081 A
0082 P
0083 E
0084 ENDα
0085 STOP
0086 SPACE
0087 SPACE
```

The File identified by the number in Register 025 is loaded into memory.

The message "Insert Program Tape" is printed.

File -8

```
0088 PRNTα
0090 *
0091 .
0092 *
0093 .
0094 *
0095 .
0096 *
0097 .
0098 *
0099 .
0100 *
0101 .
0102 *
0103 .
0104 *
0105 .
0106 ENDα
```

```
0107 RCL    R025
0109 PRNTα
0111 P
0112 R
0113 O
0114 J
0115 E
0116 C
0117 T
0118
0119 1
0120 0
0121 0
0122 0
0123 LINE
0124 D
0125 A
0126 T
0127 A
0128
0129 A
0130 N
0131 A
0132 L
0133 Y
0134 S
0135 I
0136 S
0137 LINE
0138 F
0139 O
0140 R
0141
0142 H
0143 O
0144 L
0145 E
0146
0147 N
0148 O
0149 .
0150
0151 PRINT
0152 ENDα
0153 SPACE
0154 PRNTα
0156 *
0157
0158 *
0159
0160 *
0161
0162 *
0163
0164 *
0165
0166 *
0167
0168 *
0169
0170 *
0171
0172 ENDα
```

Steps 0088 through 0172 print the message below on the tape.

```
*.*.*.*.*.*.*.*.
PROJECT 1000
DATA ANALYSIS
FOR HOLE NO.   1

* * * * * * * *
```

```
0173 RCL     R016
0175 PRNTα
0177 D
0178 A
0179 T
0180 E
0181
0182 PRINT
0183 ENDα
0184 RCL     R017
0186 PRNTα
0188 D
0189 A
0190 T
0191 A
0192
0193 S
0194 O
0195 U
0196 R
0197 C
0198 E
0199
0200 PRINT
0201 ENDα
0202 RCL     R015
0204 PRNTα
0206 D
0207 A
0208 T
0209 A
0210
0211 L
0212 O
0213 T
0214
0215 PRINT
0216 ENDα
0217 RCL     R025
0219 PRNTα
0221 H
0222 O
0223 L
0224 E
0225
0226 N
0227 O
0228 .
0229
0230 PRINT
0231 ENDα
```

Register 016 (Date of Data Entry) is recalled and printed.

Register 017 (Data Source) is recalled and printed.

```
DATE            0
DATA SOURCE     0
DATA LOT        0
HOLE NO.        1
```

Register 015 (Data Lot) is recalled and printed.

Register 025 (Hole Number) is recalled and printed.

File -8

```
0294 PRNTα
0296
0297 U
0298 P
0299 P
0300 E
0301 R
0302
```

Register 012 (Upper Limit) is recalled and printed.

```
0303 L
0304 I
0305 M
0306 I
0307 T
0308 =
0309 ENDα
0310 CLEAR
0311 RCL      R012
0313 PRINT
0314 PRNTα
0316 *
0317
0318 *
0319
0320 *
0321
0322 *
0323
0324 *
0325
0326 *
0327
0328 *
0329
0330 *
0331
0332 ENDα
```

File -9 is loaded into the computer.

```
0333 CLEAR
0334 9
0335 +÷-
0336 LD&GO
0337 END
```

```
FILE    -9
TYPE     0
USED     602
MAX      1000

0000 NOP
0001 NOP
0002 CLEAR
0003 CLRA÷J
0004 1
0005 7
0006 0
0007 #REGS
0008 FIX     6
0010 CLX
0011 4
0012 1
0013 STO     A
0014 1
0015 7
0016 0
0017 STO     F
0018 FOR     A÷F
0019 RCL I   A
0021 IF 0
0022 GOTO    D
0024 GOSUB   G
0026 NEXT    A
```

The Stack is cleared.

Register A through J are cleared and 170 Registers are opened up for data storage.

A Fix 6 is put in to print the data to 6 significant digits.

"CLX" clears the X Register in the stack.

An A-F "For Next" loop is set up.

41 is stored in Register A.

170 is stored in Register F. This loop removes the data one Register at a time starting with Register 41 and continues until it comes to a Register with no information on it (0).

When a zero is found, label D is addressed (0217).

As Data is removed by the "For Next" loop, Sub Label G is addressed.

When the SubRoutine is complete, the program returns to step 026 and recycles the A-F "For Next" loop for the next data entry.

```
0027 LBL
---- G
0029 RCL I   A
0031 STO     H
0032 SUM+
0033 CLEAR
0034 RCL     R018
0036 IF 0
0037 GOTO    L11
0039 GOTO    L12
0041 LBL
---- 11
0043 RCL     H
0044 STO     R018
0046 LBL
---- 12
0048 CLEAR
0049 RCL     R018
0051 RCL     H
0052 IF X<Y
0053 STO     R018
0055 CLEAR
0056 RCL     R014
0058 RCL     H
0059 IF X≥Y
0060 STO     R014
0062 CLEAR
```

-Label G-

Each data entry is stored in Register H and summated. The stack is cleared and Register 18 is recalled.

If Register 18 is empty (zero), label 11 is addressed.

When Register 18 contains data, label 12 is addressed.

-Label 11-

Register H is recalled.

It is stored in Register 18.

Label 12 is programmed in next.

-Label 12-

The stack is cleared.

Register 18 is recalled.

Register H is recalled and is compared to Register 18.

If Register H is smaller than Register 18, the stack is cleared.

Register 14 is recalled.

Register H is recalled and is compared to Register 14.

If Register H is equal to or greater than Register 14, it is stored in Register 14.

If Register H is smaller than Register 14, the stack is cleared.

```
0063 RCL     R011
0065 1
0066 0
0067 0
0068 0
0069 *
0070 INT
0071 STO     R000
0073 RCL     R011
0075 1
0076 0
0077 0
0078 0
0079 0
0080 *
0081 INT
0082 RCL     R000
0084 1
0085 0
0086 *
0087 -
0088 1
0089 IF X<Y
0090 GOTO    L50
0092 RCL     H
0093 RCL     R011
0095 .
0096 0
0097 0
0098 0
0099 1
0100 -
0101 IF X<Y
0102 GOTO    L03
0104 GOTO    L51
0106 LBL
---- 50
0108 RCL     H
0109 RCL     R011
0111 IF X<Y
0112 GOTO    L03
0114 LBL
---- 51
0116 RCL     H
0117 PRNTα
0119 PRINT
0120 -
0121 -
0122 -
0123 -
0124 ENDα
0125 GOTO    L06
```

Steps 0063 through 0112 analyze the value of the Lower Limit specification.

Register 011 is recalled. This number is multiplied by 1000 and its integer is taken. This number is stored in Register 000.

Register 011 is recalled again and is multiplied by 10,000. The integer of this number is taken.

Register 000 is recalled and multiplied by 10.

This number is then subtracted from the above number.

If the difference is greater than one, Label 50 is addressed.

If the difference is one or zero, Register H is recalled. Register 011 is recalled and .0001 is subtracted from it. This number is compared to Register H.

If Register H is greater than that number, Label 03 is addressed.

If Register H is less than that number Label 51 is addressed.

- Label 50 -

Register H is recalled. Register 011 is recalled. These numbers are compared.

If Register 011 is less than Register H, Label 03 is addressed. This label analyzes the Upper Limit specification.

If Register 011 is greater than Register H, Label 51 is addressed.

- Label 51 -

Register H is recalled. It is printed with 4 minus signs (----) to signify an out of tolerance condition. Label 06 is then addressed.

- Label 03 -

```
0127 LBL
---- 03
0129 RCL     R012
0131 1
0132 0
0133 0
0134 0
0135 *
0136 INT
0137 STO     R000
0139 RCL     R012
0141 1
0142 0
0143 0
0144 0
0145 0
0146 *
0147 INT
0148 RCL     R000
0150 1
0151 0
0152 *
0153 -
0154 1
0155 IF X<Y
0156 GOTO    L52
0158 RCL     R012
0160 .
0161 0
0162 0
0163 0
0164 5
0165 +
0166 RCL     H
0167 IF X<Y
0168 GOTO    L04
0170 GOTO    L53
```

Steps 0129 through 0170 analyze the value of the Upper Limit specification.

Register 012 (Upper Limit Tolerance) is recalled. This number is multiplied by 1000. The integer of this number is taken and it is stored in Register 000.

Register 012 is recalled. It is multiplied by 10,000. The integer of this number is taken.

Register 000 is recalled and it is multiplied by 10. This number is now subtracted from the number just above.

If the difference is greater than one, Label 52 is addressed.

If the difference is less than one, Register 012 is recalled and .0005 is added to it. Register H is recalled and compared to that number.

If Register H is less than that number, Label 04 is addressed.

If Register H is greater than that number, Label 53 is addressed.

- Label 52 -

```
0172 LBL
---- 52
0174 RCL     R012
0176 RCL     H
0177 IF X<Y
0178 GOTO    L04
```

Label 52 recalls Registers 012 and H. They are compared.

If Register H is less than Register 012 Label 04 is addressed.

If Register H is greater than Register 012 Label 53 is programmed in.

- Label 53 -

```
0180 LBL
---- 53
0182 PRNTα
0184 PRINT
0185 +
0186 +
0187 +
0188 +
0189 ENDα
0190 GOTO    L06
```

Label 53 prints the data with 4 plus signs (++++) to signify an out of tolerance condition. Label 06 is then addressed.

- Label 04 -

```
0192 LBL
---- 04
0194 RCL     H
0195 PRINT
0196 GOTO    L06
```

Label 04 recalls Register H and prints the data on the tape. Label 06 is then addressed.

- Label 06 -

```
0198 LBL
---- 06
0200 RCL     A
0201 4
0202 ÷
0203 STO     R000
0205 INT
0206 STO     R002
0208 RCL     R000
0210 RCL     R002
0212 -
0213 IF 0
0214 SPACE
0215 RCL     H
0216 RETURN
```

Register A is recalled. It is divided by 4 and stored in Register 000. The integer of the number is taken. This number is stored Register 002.

Register 002 is subtracted from Register 000.

If there is no difference, a space is inserted on the tape. Register H is recalled and the program returns to Step 0026.

If there is a difference, Register H is recalled and the Program returns to Step 0026.

- Label D -

```
0217 LBL
---- D
0219 LBL
---- D
0221 RCL     C
0222 STO     R023
0224 RCL     D
0225 STO     R024
0227 RCL     E
0228 STO     R026
0230 MN&SD
0231 STO     R019
0233 X⇌Y
0234 STO     R020
```

Register C is recalled and stored in Register 023.

Register D is recalled and stored in Register 024.

Register E is recalled and stored in Register 026.

Mean is stored in Register 019.
Standard deviation is stored in Register 020.

```
0236 PRNTα
0238 *
0239
0240 *
0241
0242 *
0243
0244 *
0245
0246 *
0247
0248 *
0249
0250 *
0251
0252 *
0253
0254 ENDα
0255 PRNTα
0257
0258
0259 E
0260 N
0261 D
0262
0263 O
0264 F
0265
0266 D
0267 A
0268 T
0269 A
0270 ENDα
0271 PRNTα
0273
0274
0275
0276
0277
0278
0279 *
0280 *
0281 *
0282 ENDα
0283 SPACE
0284 PRNTα
0286 =
0287
0288 =
0289
0290 =
0291
0292 =
0293
0294 =
0295
0296 =
0297
0298 =
0299
0300 =
0301
0302 ENDα
0303 RCL     A
0304 FIX     0
0306 4
0307 1
0308 -
0309 STO     R013
0311 PRNTα
0313 PRINT
0314
0315 D
0316 A
0317 T
0318 A
0319
0320 E
0321 N
0322 T
0323 R
0324 I
0325 E
0326 S
0327 ENDα
0328 PRNTα
0330 =
0331
0332 =
0333
0334 =
0335
0336 =
0337
0338 =
0339
0340 =
0341
0342 =
0343
0344 =
0345
0346 ENDα
```

Steps 0236 through 0346 print the message below.

```
* * * * * * * *
  END OF DATA
      ***

= = = = = = = =
 20 DATA ENTRIES
= = = = = = = =
```

Register A is recalled. 41 is subtracted from it. This number is stored in Register 13.

Register 13 stores the number of data entries.

```
0347 SPACE
0348 PRNTα
0350 H
0351 O
0352 L
0353 E
0354
0355 S
0356 I
0357 Z
0358 E
0359 *
0360 ENDα
0361 PRNTα
0363
0364
0365 U
0366 P
0367 P
0368 E
0369 R
0370
0371 L
0372 I
0373 M
0374 I
0375 T
0376 =
0377 ENDα
0378 FIX      6
0380 RCL      R012
0382 PRINT
0383 PRNTα
0385
0386
0387 L
0388 O
0389 W
0390 E
0391 R
0392
0393 L
0394 I
0395 M
0396 I
0397 T
0398 =
0399 ENDα
0400 RCL      R011
0402 PRINT
```

Steps 0347 through 0422 print the message below:

Register 012 is recalled (Upper Limit) and printed.

```
HOLE SIZE*
  UPPER LIMIT=
    0.315000
  LOWER LIMIT=
    0.312000
= = = = = = = =
```

Register 011 is recalled (Lower Limit) and printed.

```
0403 PRNTα
0405 =
0406
0407 =
0408
0409 =
0410
0411 =
0412
0413 =
0414
0415 =
0416
0417 =
0418
0419 =
0420
0421 ENDα
0422 SPACE
```

File -9

Steps 0423 through 0489 print the message below.

```
HIGHEST READING=
    0.313391
       ***
LOWEST READING=
    0.313090
       ***
```

```
0423 PRNTα
0425 H
0426 I
0427 G
0428 H
0429 E
0430 S
0431 T
0432
0433 R
0434 E
0435 A
0436 D
0437 I
0438 N
0439 G
0440 =
0441 ENDα
0442 RCL      R014
0444 PRINT
```

Register 014 is recalled (Highest Reading) and printed.

```
0445 PRNTα
0447
0448
0449
0450
0451
0452
0453 *
0454 *
0455 *
0456 ENDα
0457 PRNTα
0459 L
0460 O
0461 W
0462 E
0463 S
0464 T
0465
0466 R
0467 E
0468 A
0469 D
0470 I
0471 N
0472 G
0473 =
0474 ENDα
0475 RCL      R018
0477 PRINT
```

Register 018 is recalled (Lowest Reading) and printed.

```
0478 PRNTα
0480
0481
0482
0483
0484
0485
0486 *
0487 *
0488 *
0489 ENDα
```

```
0490 PRNTα
0492 M
0493 A
0494 X
0495 .
0496
0497 O
0498 V
0499 E
0500 R
0501 S
0502 I
0503 Z
0504 E
0505 =
0506 ENDα
0507 RCL      R014
0509 RCL      R012
0511 -
0512 IF -
0513 0
0514 PRNTα
0516
0517
0518
0519
0520 +
0521 +
0522 +
0523 +
0524 PRINT
0525 ENDα
0526 PRNTα
0528
0529
0530
0531
0532
0533
0534 *
0535 *
0536 *
0537 ENDα
0538 PRNTα
0540 M
0541 A
0542 X
0543 .
0544
0545 U
0546 N
0547 D
0548 E
0549 R
0550 S
0551 I
0552 Z
0553 E
0554 =
0555 ENDα
```

Steps 0490 through 0593 print the message below:

Registers 014 and 012 are recalled.

```
MAX. OVERSIZE=
     ++++0.000000
        ***
MAX. UNDERSIZE=
     ----0.000000
= = = = = = = =
```

Register 012 is subtracted from 014.

If the answer is negative, there is no oversize.

If the answer is positive, the number is printed as oversized.

```
0556 RCL      R011
0558 RCL      R018
0560 -
0561 IF -
0562 0
0563 PRNTα
0565
0566
0567
0568
0569 -
0570 -
0571 -
0572 -
0573 PRINT
0574 ENDα
0575 PRNTα
0577 =
0578
0579 =
0580
0581 =
0582
0583 =
0584
0585 =
0586
0587 =
0588
0589 =
0590
0591 =
0592
0593 ENDα
0594 FIX      0
0596 CLEAR
0597 1
0598 0
0599 +÷-
0600 LD&GO
0601 END
```

Register 011 and 018 are recalled.

Register 018 is subtracted from 011.

If the answer is negative there is no undersize.

If the answer is positive the number is printed as undersized.

File -10 is loaded into the computer.

```
FILE    -10
TYPE     0
USED     500
MAX      1000

0000 NOP
0001 NOP
0002 NOP
0003 NOP
0004 NOP
0005 NOP
0006 NOP
0007 NOP
0008 NOP
0009 NOP
0010 NOP
0011 NOP
0012 FIX      6
0014 SPACE
0015 PRNTα
0017 R
0018 A
0019 N
0020 G
0021 E
0022
0023 O
0024 F
0025
0026 D
0027 A
0028 T
0029 A
0030 =
0031 ENDα
0032 RCL      R014
0034 RCL      R018
0036 -
0037 PRINT
0038 PRNTα
0040 =
0041
0042 =
0043
0044 =
0045
0046 =
0047
0048 =
0049
0050 =
0051
0052 =
0053
0054 =
0055
0056 ENDα
```

A Fix 6 is programmed in to print the data to 6 significant places.

Steps 0015 through 0056 print the message below:

```
RANGE OF DATA=
    0.000301
= = = = = = = =
```

Register 014 is recalled.

Register 18 is recalled and subtracted from 014.

The difference is labeled as the "Range of Data."

```
0057 SPACE
0058 PRNT∝
0060 A
0061 R
0062 I
0063 T
0064 H
0065 .
0066
0067 M
0068 E
0069 A
0070 N
0071 =
0072 END∝
```

Steps 0058 through 0149 print the message below:

```
ARITH. MEAN=
    0.313239
STD. DEV.=
    0.000094
STD. ERROR=
    0.000021
= = = = = = = =
      ***
```

```
0073 FIX    6
0075 RCL    R019
```

Register 019 is recalled (Mean) and printed.

```
0077 PRINT
0078 PRNT∝
0080 S
0081 T
0082 D
0083 .
0084
0085 D
0086 E
0087 V
0088 .
0089 =
0090 END∝
0091 RCL    R020
0093 PRINT
```

Register 020 is recalled (Standard Deviation) and printed.

```
0094 RCL    R013
```

Register 013 (Number of Entries) is recalled.

```
0096 SQRT
0097 STO    A
```

The square root is taken and that number is stored in Register A.

```
0098 RCL    R020
0100 RCL    A
0101 ÷
```

Register 20 (Standard Deviation) is recalled and Register A is divided into it.

```
0102 STO    A
```

The result is stored in Register A.

```
0103 PRNT∝
0105 S
0106 T
0107 D
0108 .
0109
0110 E
0111 R
0112 R
0113 O
0114 R
0115 =
0116 END∝
0117 RCL    A
0118 PRINT
```

Register A (Standard Error) is recalled and printed.

```
0119 PRNTα
0121 =
0122
0123 =
0124
0125 =
0126
0127 =
0128
0129 =
0130
0131 =
0132
0133 =
0134
0135 =
0136
0137 ENDα
0138 PRNTα
0140
0141
0142
0143
0144
0145
0146 *
0147 *
0148 *
0149 ENDα
0150 SPACE
0151 SPACE
0152 SPACE
```

```
0153 FIX    0
0155 RCL    R025
0157 PRNTα
0159 H
0160 O
0161 L
0162 E
0163
0164 N
0165 O
0166 .
0167
0168 PRINT
0169 ENDα
0170 PRNTα
0172 *
0173
0174 *
0175
0176 *
0177
0178 *
0179
0180 *
0181
0182 *
0183
0184 *
0185
0186 *
0187 ENDα
0188 PRNTα
0190 0
0191
0192
0193 D
0194 E
0195 G
0196 .
0197
0198 A
0199 L
0200 I
0201 G
0202 N
0203 M
0204 T
0205 ENDα
```

Register 025 (Hole Number) is recalled and printed.

The Header "O DEG. ALIGNMT" is printed.

```
0206 CLEAR
0207 FIX     6
0209 4
0210 1
0211 STO     C
0212 1
0213 7
0214 0
0215 STO     H
0216 4
0217 STO     D
0218 FOR     C→HD
0219 RCL I   C
0221 IF 0
0222 GOTO    L18
0224 PRINT
0225 NEXT    C
0226 LBL
---- 18
0228 RCL     C
0229 STO     A
0230 3
0231 +
0232 STO     F
0233 FOR     A→F
0234 RCL     A
0235 0
0236 STO I   A
0238 NEXT    A
0239 GOTO    L20
```

A Fix 6 is programmed in to print the data to 6 significant places.

Steps 209 through 238 set up a "For Next" loop. 41 is stored in Register C.

170 is stored in Register H

4 is stored in Register D to recall indirectly the data stored in increments of 4.

When it encounters a zero value it programs in label 18.

Label 18 deletes any data entries that might be in other axes even though there was a zero value in the zero axis.

At the end of this process Label 20 is addressed.

- Label 20 -

```
0241 LBL
---- 20
0243 SPACE
0244 PRNTα
0246 4
0247 5
0248
0249 D
0250 E
0251 G
0252 .
0253
0254 A
0255 L
0256 I
0257 G
0258 N
0259 M
0260 T
0261 ENDα
0262 4
0263 2
0264 STO     C
0265 1
0266 7
0267 0
0268 STO     H
0269 4
0270 STO     D
0271 FOR     C→HD
0272 RCL I   C
0274 IF 0
0275 GOTO    L21
0277 PRINT
0278 NEXT    C
```

In this label the Header "45 DEG. ALIGNMT" is printed.

Steps 0262 through 0278 set up a "For Next" loop.

42 is stored in Register C.

170 is stored in Register H.

4 is stored in Register D to recall indirectly the data stored in increments of 4.

When it encounters a zero value label 21 is addressed.

- Label 21 -

```
0279 LBL
---- 21
0281 SPACE
0282 PRNTα
0284 9
0285 0
0286
0287 D
0288 E
0289 G
0290 .
0291
0292 A
0293 L
0294 I
0295 G
0296 N
0297 M
0298 T
0299 ENDα
0300 4
0301 3
0302 STO     C
0303 1
0304 7
0305 0
0306 STO     H
0307 4
0308 STO     D
0309 FOR     C→HD
0310 RCL I   C
0312 IF 0
0313 GOTO    L22
0315 PRINT
0316 NEXT    C
```

In this label the Header "90 DEG. ALIGNMNT" is printed.

Steps 0300 through 0316 set up a "For Next" Loop.

43 is stored in Register C.

170 is stored in Register H.

4 is stored in Register D to recall indirectly the data stored in increments of 4.

When it encounters a zero value, Label 22 is addressed.

- Label 22 -

In this label the Header "135 DEG. ALIGNMT" is printed.

```
0317 LBL
---- 22
0319 SPACE
0320 PRNTα
0322 1
0323 3
0324 5
0325
0326 D
0327 E
0328 G
0329 .
0330
0331 A
0332 L
0333 I
0334 G
0335 N
0336 M
0337 T
0338 ENDα
```

Steps 0339 through 0355 set up a "For Next" Loop.

44 is stored in Register C.

170 is stored in Register H.

4 is stored in Register D to recall indirectly the data stored in increments of 4.

When it encounters a zero value Label 23 is addressed

```
0339 4
0340 4
0341 STO      C
0342 1
0343 7
0344 0
0345 STO      H
0346 4
0347 STO      D
0348 FOR      C→HD
0349 RCL  I   C
0351 IF 0
0352 GOTO     L23
0354 PRINT
0355 NEXT     C
```

- Label 23 -

This label prints asterisks below all the alignment data.

```
0356 LBL
---- 23
0358 PRNTα
0360 *
0361
0362 *
0363
0364 *
0365
0366 *
0367
0368 *
0369
0370 *
0371
0372 *
0373
0374 *
0375
0376 ENDα
0377 PRNTα
0379
0380
0381
0382
0383
0384
0385 *
0386 *
0387 *
0388 ENDα
0389 SPACE
0390 SPACE
0391 SPACE
```

```
0392 CLRA→J
0393 CLEAR
0394 FIX      6
0396 4
0397 1
0398 STO      C
0399 1
0400 7
0401 0
0402 STO      H
0403 4
0404 STO      D
0405 FOR      C→HD
0406 RCL I    C
0408 STO      B
0409 IF 0
0410 GOTO     L24
0412 RCL      E
0413 1
0414 +
0415 STO      E
0416 GOSUB    A
0418 NEXT     C
0419 LBL
---- A
0421 RCL      E
0422 4
0423 *
0424 3
0425 9
0426 +
0427 STO      A
0428 1
0429 7
0430 0
0431 STO      F
0432 FOR      A→F
0433 RCL I    A
0435 IF 0
0436 RETURN
0437 STO      G
0438 RCL      B
0439 -
0440 IF -
0441 GOTO     B
0443 RCL      I
0444 IF X=Y
0445 GOTO     D
0447 X⇌Y
0448 IF X≥Y
0449 GOTO     C
0451 GOTO     D
```

Steps 0392 through 0492 analyze the data for the maximum ovality between the 0 degree and 90 degree axes.

Registers A through J are cleared.

A CDH "For Next" Loop is used with 41 stored in Register C.

170 stored in Register H.

4 stored in Register D.

In increments of four a value is taken from the zero axis (RCL I C) and stored in Register B.

Register E is recalled and one is added to it.

Sublabel A is addressed.

- Label A -

Register E is recalled and multiplied by 4. 39 is added to it and it is stored in Register A.

170 is stored in Register F.

A A - F for next Loop is used here to program the corresponding value in the 90 degree axis of the same level to be unloaded (step 0433) and stored in Register G.

Register B is recalled and is subtracted from Register G.

If the answer is negative, Label B is addressed.

If the answer is positive, Register I is recalled and the positive answer is compared to it.

If they equal, Label D is addressed.

If the positive answer is equal to or greater than Register I, Label C is addressed.

If the positive answer is less than Register I, Label D is addressed.

```
0453 LBL
---- B
0455 RCL     B
0456 RCL     G
0457 -
0458 RCL     I
0459 IF X=Y
0460 GOTO    D
0462 X⇌Y
0463 IF X≥Y
0464 GOTO    C
0466 GOTO    D
0468 LBL
---- C
0470 STO     I
0471 STO     R021
0473 RCL     E
0474 STO     R022
0476 LBL
---- D
0478 CLEAR
0479 RETURN
0480 LBL
---- 24
0482 RCL     C
0483 STO     A
0484 3
0485 +
0486 STO     F
0487 FOR     A→F
0488 RCL     A
0489 0
0490 STO I   A
0492 NEXT    A
0493 CLRA→J
0494 CLEAR
0495 1
0496 1
0497 +⇌-
0498 LD&GO
0499 END
```

-Label B-

This label is addressed when the difference between Register B and Register G is negative.

In this label Register B is recalled.

Register G is recalled and subtracted from B.

Register I is recalled and compared to the difference. If they equal, Label D is addressed.

If the difference is greater than Register I, Label C is addressed.

If the difference is less than Register I, Label D is addressed.

-Label C-

This label stores the difference between Register G and Register B in Register I and Register 21.

Register E is recalled and is stored in Register 22.

-Label D-

This label clears the stack and returns the program to step 0418.

-Label 24-

This label clears the Registers of the last level if there is a zero value in the zero axis (from Step 0410).

Register C is recalled and stored in Register Z. 3 is added to that number and is stored in F. This sets up a "For Next" Loop which puts zeros in the 3 Register preceding the first empty Register of the zero axis.

Registers A through J are cleared.

The Stack is cleared.

File -11 is loaded into the computer.

```
FILE    -11
TYPE     0
USED    239
MAX     1000

0000 FIX      6
0002 4
0003 2
0004 STO      C
0005 1
0006 7
0007 0
0008 STO      H
0009 4
0010 STO      D
0011 FOR      C+HD
0012 RCL I    C
0014 STO      B
0015 IF 0
0016 GOTO     L25
0018 RCL      E
0019 1
0020 +
0021 STO      E
0022 GOSUB    A
0024 NEXT     C
0025 LBL
----A
0027 RCL      E
0028 4
0029 *
0030 4
0031 0
0032 +
0033 STO      A
0034 1
0035 7
0036 0
0037 STO      F
0038 FOR      A+F
0039 RCL I    A
0041 IF 0
0042 RETURN
0043 STO      G
0044 RCL      B
0045 -
0046 IF -
0047 GOTO     B
0049 RCL      I
0050 IF X=Y
0051 GOTO     D
0053 X≠Y
0054 IF X≥Y
0055 GOTO     C
0057 GOTO     D
```

Steps 0000 through 0085 analyze the data for the maximum ovality between the 45 degress and 135 degree areas.

A C,D,H "For Next" Loop is used to scan all the data and select the data required for this evaluation.

42 is stored in Register C.

170 is stored in Register H.

4 is stored in Register D. (Register 42 has the first 45 degree entry stored in it).

Data for the 45 degree entry is stored in Register B.

When there is no more data in the 45 degree axis, Label 25 is addressed.

Register E is recalled, 1 is added to it and it is restored in Register E. This Register is used as a counter to keep track of the corresponding value in the 135 degree axis.

Sublabel A is addressed.

-Label A-

Register E is recalled and multiplied by 4. 40 is added to this number and it is stored in Register A.

170 is stored in Register F.

The A-F "For Next" Loop recalls the corresponding data from the 135 degree axis and stores the value in Register G.

Register B is recalled and subtracted from Register G.

If the answer is negative, Label B is addressed.

If the answer is positive, it is compared to Register I.

If they equal, label D is addressed.

If Register I is less than the positive an wer, Label C is addressed.

If Register I is greater than the positive answer, Label D is addressed.

```
0059 LBL
---- B
0061 RCL      B
0062 RCL      G
0063 -
0064 RCL      I
0065 IF  X=Y
0067 GOTO     D
0068 X⇌Y
0069 IF  X≥Y
0070 GOTO     C
0072 GOTO     D
```

-Label B-

In this label Register B is recalled.

Register G is recalled and subtracted from Register B.

The difference is compared to Register I.

If they equal, label D is addressed.

If the difference is greater than Register I, Label C is addressed.

If the difference is less than Register I, Label D is addressed.

```
0074 LBL
---- C
0076 STO      I
0077 STO      R027
0079 RCL      E
0080 STO      R028
0082 LBL
---- D
0084 CLEAR
0085 RETURN
```

-Label C-

In this label the difference value is stored in Registers I and 027.

Register E is recalled and stored in Register 028.

Label D is then programmed in.

-Label D-

In this label the stack is cleared.

The Program then returns to Step 0024 to continue the "For Next" loop.

In Label 25 the message below is printed on the tape.

```
0086 LBL
---- 25
0088 PRNTα
0090 =
0091
0092 =
0093
0094 =
0095
0096 =
0097
0098 =
0099
0100 =
0101
0102 =
0103
0104 =
0105
0106 ENDα
0107 SPACE
0108 PRNTα
0110 M
0111 A
0112 X
0113 .
0114
0115 O
0116 V
0117 A
0118 L
0119 .
0120
0121 0
0122 -
0123 9
0124 0
0125 ENDα
0126 RCL      R021
0128 PRINT
0129 FIX      0
0131 RCL      R022
0133 PRNTα
0135
0136
0137 A
0138 T
0139
0140 L
0141 E
0142 V
0143 E
0144 L
0145
0146 PRINT
0147 ENDα
```

```
= = = = = = = =

MAX. OVAL. 0-90
    0.000126
  AT LEVEL     3
      ***
MAX.OVAL.45-135
    0.000121
  AT LEVEL     4
= = = = = = = =
      ***
```

Register 21 is recalled (Maximum Ovality 0-90 Degree) and printed.

Register 22 is recalled (Level of Max. Ovality) and printed.

```
0148 PRNTα
0150
0151
0152
0153
0154
0155
0156 *
0157 *
0158 *
0159 ENDα
0160 FIX      6
0162 PRNTα
0164 M
0165 A
0166 X
0167 .
0168 O
0169 V
0170 A
0171 L
0172 .
0173 4
0174 5
0175 -
0176 1
0177 3
0178 5
0179 ENDα
0180 RCL      R027
0182 PRINT
0183 FIX      0
0185 RCL      R028
0187 PRNTα
0189
0190
0191 A
0192 T
0193
0194 L
0195 E
0196 V
0197 E
0198 L
0199
0200 PRINT
0201 ENDα
```

Register 27 is recalled (Maximum Ovality 45-135 Degree) and printed.

Register 28 is recalled (Level of Maximum Ovality) and printed.

```
0202 PRNTα
0204 =
0205
0206 =
0207
0208 =
0209
0210 =
0211
0212 =
0213
0214 =
0215
0216 =
0217
0218 =
0219
0220 ENDα
0221 PRNTα
0223
0224
0225
0226
0227
0228
0229 *
0230 *
0231 *
0232 ENDα
0233 CLEAR
0234 1
0235 2
0236 +⇌-
0237 LD&GO
0238 END
```

File -12 is loaded into the computer.

```
FILE    -12
TYPE     0
USED     72
MAX      1000

0000 NOP
0001 NOP
0002 SPACE
0003 SPACE
0004 SPACE
0005 SPACE
0006 SPACE
0007 SPACE
0008 NOP
0009 FIX      0
0011 RCL      R025
0013 PRNTα
0015 H
0016 O
0017 L
0018 E
0019
0020 N
0021 O
0022 .
0023
0024 PRINT
0025 ENDα
0026 PRNTα
0028 *
0029
0030 *
0031
0032 *
0033
0034 *
0035
0036 *
0037
0038 *
0039
0040 *
0041
0042 *
0043
0044 ENDα
```

File -12 prints the Heater information for the Hole Profile Analysis as shown below.

```
HOLE NO.         1
* * * * * * * *
--HOLE PROFILE--
```

Register 25 is recalled (Hole No.) and printed.

```
0045 PRNTα
0047 -
0048 -
0049 H
0050 O
0051 L
0052 E
0053
0054 P
0055 R
0056 O
0057 F
0058 I
0059 L
0060 E
0061 -
0062 -
0063 ENDα
0064 CLEAR
0065 1
0066 3
0067 +÷-
0068 LD&GO
0069 LBL
---- 99
0071 END
```

File -13 is loaded into the computer.

```
FILE    -13
TYPE     0
USED     416
MAX      1000

0000 NOP
0001 NOP
0002 CLRA→J
0003 FIX      0
0005 1
0006 3
0007 +⇌-
0008 STO      R033
0010 PRNTα
0012 0
0013
0014 D
0015 E
0016 G
0017 .
0018
0019 A
0020 L
0021 I
0022 G
0023 N
0024 M
0025 T
0026 ENDα
0027 CLEAR
0028 FIX      6
0030 4
0031 1
0032 STO      A
0033 STO      C
0034 1
0035 7
0036 0
0037 STO      H
0038 4
0039 STO      D
0040 FOR      C→HD
0041 RCL I    C
0043 IF 0
0044 GOTO     L31
0046 STO      J
0047 GOSUB    L50
0049 NEXT     C
```

File -13 analyzes the data taken and prints a Histogram of the Hole Profile for the "0" Degree axis.

-13 is stored in Register 33.

The message "0 Deg. Alignmt" is printed.

A Fix 6 is used to analyze the data up to six significant digits.

A C,D,H "For Next" Loop is used to scan the data and analyze the data for the "0" Degree axis only.

41 is stored in Registers A and C.

170 is stored in Register H.

4 is stored in Register D to withdraw the data in increments of 4.

The data is stored in Register J and then GoSub Label 50 is addressed.

When there is no more data to analyze, Label 31 is addressed.

```
0050 LBL
---- 50
0052 CLEAR
0053 RCL     B
0054 IF 0
0055 GOTO    L32
0057 GOTO    L33
```

-Label 50-

In Label 50 first the stack is cleared.

Register B is recalled.

If there is a zero in Register B, Label 32 is addressed.

If there is data in Register B, Label 33 is addressed.

```
0059 LBL
---- 32
0061 RCL     J
0062 STO     B
0063 LBL
---- 33
0065 CLEAR
0066 RCL     B
0067 RCL     J
0068 IF X<Y
0069 STO     B
0070 CLEAR
0071 RCL     E
0072 RCL     J
0073 IF X≥Y
0074 STO     E
0075 RETURN
```

-Label 32-

In this label Register J is recalled and stored in Register B.

Label 33 is programmed in next.

-Label 33-

In this label first the stack is cleared.

Register B is recalled.

Register J is recalled and compared to Register B.

If Register J is less than Register B, it is stored in Register B.

If Register J is equal to or greater than Register B, the stack is cleared.

Register E is recalled.

Register J is recalled and compared to Register E.

If Register J is greater than or equal to Register E, it is stored in Register E. Then the program returns to Step 0049.

If Register J is less than Register E, the Program returns to Step 0049.

```
0076 LBL
-  - 31
0078 CLEAR
0079 RCL     E
0080 RCL     B
0081 -
0082 1
0083 0
0084 0
0085 0
0086 0
0087 *
0088 INT
0089 STO     F
0090 RCL     E
0091 RCL     B
0092 -
0093 1
0094 0
0095 0
0096 0
0097 0
0098 0
0099 *
0100 STO     G
0101 1
0102 0
0103 ÷
0104 INT
0105 1
0106 0
0107 *
0108 STO     I
0109 RCL     G
0110 RCL     I
0111 -
0112 5
0113 IF X<Y
0114 GOTO    L25
0116 GOTO    L26
0118 LBL
---- 25
0120 RCL     F
0121 1
0122 +
0123 INT
0124 STO     F
0125 LBL
---- 26
0127 RCL     F
0128 1
0129 5
0130 IF X<Y
0131 GOTO    L52
0133 GOTO    L51
```

-Label 31-

Label 31 gets addressed when Indirect C contains a zero from the "For Next" Loop.

Register E is recalled.

Register 13 is recalled and subtracted from Register E.

The difference is multiplied by 10,000 and the integer is determined.

The result is stored in Register F.

Register E is recalled.

Register B is recalled and subtracted from Register E.

The difference is multiplied by 100,000 and stored in Register G.

The difference is also divided by 10 and the integer is determined. This number is multiplied by 10 and stored in Register I.

Register G is recalled. Register I is recalled and subtracted from Register G.

If the difference is greater than 5, Label 25 is addressed.

If the difference is less than 5, Label 26 is addressed.

-Label 25-

In this label Register F is recalled. 1 is added to it, its integer is determined and it is restored in Register F. Label 26 is programmed in next.

-Label 26-

In this label Register F is recalled. It is compared to the number 15.

If it is greater than 15, Label 52 is addressed.

If it is less than 15, Label 51 is addressed.

```
0135 LBL
---- 51
0137 CLEAR
0138 FIX     6
0140 4
0141 1
0142 STO     C
0143 1
0144 7
0145 0
0146 STO     H
0147 4
0148 STO     D
0149 FOR     C→HD
0150 RCL  I  C
0152 STO     J
0153 STO     E
0154 IF 0
0155 GOTO    L98
0157 RCL     B
0158 -
0159 1
0160 0
0161 0
0162 0
0163 0
0164 *
0165 INT
0166 GOSUB   LX
0167 NEXT    C
```

-Label 51-

If the range of data is less than a thousandths and a half, Label 51 is addressed.

In this label, first the stack is cleared.

Fix 6 is programmed in to calculate the data to six significant places.

A C,D,H "For Next" loop is used.

41 is stored in Register C.

170 is stored in Register H.

4 is stored in Register D.

The Data is stored in Registers J and E.

When Indirect C contains a zero from the "For Next" Loop, label 98 gets addressed.

Register B is recalled (smallest data number in axis) and the difference between Registers E and B is taken.

This number is multiplied by 10,000 and the integer is determined.

The resulting value will have a number ranging between 0 and 15. This number is used to address the corresponding label which will print the corresponding zeros to produce a cross-sectional view of that particular axis for each level of data entry.

```
0168 LBL
---- 00
0170 PRNTα
0172 *
0173 ENDα
0174 RETURN
0175 LBL
---- 01
0177 PRNTα
0179 *
0180 0
0181 ENDα
0182 RETURN
0183 LBL
---- 02
0185 PRNTα
0187 *
0188 0
0189 0
0190 ENDα
0191 RETURN
0192 LBL
---- 03
0194 PRNTα
0196 *
0197 0
0198 0
0199 0
0200 ENDα
0201 RETURN
0202 LBL
---- 04
0204 PRNTα
0206 *
0207 0
0208 0
0209 0
0210 0
0211 ENDα
0212 RETURN
0213 LBL
---- 05
0215 PRNTα
0217 *
0218 0
0219 0
0220 0
0221 0
0222 0
0223 ENDα
0224 RETURN
0225 LBL
---- 06
0227 PRNTα
0229 *
0230 0
0231 0
0232 0
0233 0
0234 0
0235 0
0236 ENDα
0237 RETURN
0238 LBL
---- 07
0240 PRNTα
0242 *
0243 0
0244 0
0245 0
0246 0
0247 0
0248 0
0249 0
0250 ENDα
0251 RETURN
0252 LBL
---- 08
0254 PRNTα
0256 *
0257 0
0258 0
0259 0
0260 0
0261 0
0262 0
0263 0
0264 0
0265 ENDα
0266 RETURN
0267 LBL
---- 09
0269 PRNTα
0271 *
0272 0
0273 0
0274 0
0275 0
0276 0
0277 0
0278 0
0279 0
0280 0
0281 ENDα
0282 RETURN
```

```
0283 LBL
---- 10
0285 PRNTα
0287 *
0288 0
0289 0
0290 0
0291 0
0292 0
0293 0
0294 0
0295 0
0296 0
0297 0
0298 ENDα
0299 RETURN
0300 LBL
---- 11
0302 PRNTα
0304 *
0305 0
0306 0
0307 0
0308 0
0309 0
0310 0
0311 0
0312 0
0313 0
0314 0
0315 0
0316 ENDα
0317 RETURN
0318 LBL
---- 12
0320 PRNTα
0322 *
0323 0
0324 0
0325 0
0326 0
0327 0
0328 0
0329 0
0330 0
0331 0
0332 0
0333 0
0334 0
0335 ENDα
0336 RETURN
0337 LBL
---- 13
0339 PRNTα
0341 *
0342 0
0343 0
0344 0
0345 0
0346 0
0347 0
0348 0
0349 0
0350 0
0351 0
0352 0
0353 0
0354 0
0355 ENDα
0356 RETURN
0357 LBL
---- 14
0359 PRNTα
0361 *
0362 0
0363 0
0364 0
0365 0
0366 0
0367 0
0368 0
0369 0
0370 0
0371 0
0372 0
0373 0
0374 0
0375 0
0376 ENDα
0377 RETURN
```

File -13

```
0378 LBL
---- 15
0380 PRNTα
0382 *
0383 0
0384 0
0385 0
0386 0
0387 0
0388 0
0389 0
0390 0
0391 0
0392 0
0393 0
0394 0
0395 0
0396 0
0397 0
0398 ENDα
0399 RETURN
0400 NOP
0401 LBL
---- 52
0403 CLEAR
0404 1
0405 7
0406 +÷-
0407 LD&GO
0408 NOP
0409 LBL
---- 98
0411 1
0412 4
0413 +÷-
0414 LD&GO
0415 END
```

- Label 52 -

This label loads File -17 into the computer.

- Label 98 -

This label loads File -14 into the computer.

```
0378 LBL
---- 15
0380 PRNTα
0382 *
0383 0
0384 0
0385 0
0386 0
0387 0
0388 0
0389 0
0390 0
0391 0
0392 0
0393 0
0394 0
0395 0
0396 0
0397 0
0398 ENDα
0399 RETURN
0400 NOP
0401 LBL
---- 52
0403 CLEAR
0404 1
0405 7
0406 +÷-
0407 LD&GO
0408 NOP
0409 LBL
---- 98
0411 1
0412 4
0413 +÷-
0414 LD&GO
0415 END
```

- Label 52 -

This label loads File -17 into the computer.

- Label 98 -

This label loads File -14 into the computer.

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```
FILE    -14
TYPE     0
USED     416
MAX      1000
```

File -14 is basically identical to File -13 except that it analyzes the data taken and prints a Histogram of the Hole Profile for the 45 degree axis.

```
0000 NOP
0001 NOP
0002 CLRA→J
0003 1
0004 4
0005 +÷-
0006 STO      R033
```

-14 is stored in Register 33.

```
0008 SPACE
0009 PRNTα
0011 4
0012 5
0013
0014 D
0015 E
0016 G
0017 .
0018
0019 A
0020 L
0021 I
0022 G
0023 N
0024 M
0025 T
0026 ENDα
```

The message "45 Deg. Alignmt." is printed.

```
0027 CLEAR
0028 FIX      6
0030 4
0031 2
0032 STO      A
0033 STO      C
0034 1
0035 7
0036 0
0037 STO      H
0038 4
0039 STO      D
0040 FOR      C→HD
0041 RCL I    C
0043 IF 0
0044 GOTO     L31
0046 STO      J
0047 GOSUB    L50
0049 NEXT     C
0050 LBL
---- 50
0052 CLEAR
0053 RCL      B
0054 IF 0
0055 GOTO     L32
```

```
0050 LBL
---- 50
0052 CLEAR
0053 RCL     B
0054 IF 0
0055 GOTO    L32
0057 GOTO    L33
0059 LBL
---- 32
0061 RCL     J
0062 STO     B
0063 LBL
---- 33
0065 CLEAR
0066 RCL     B
0067 RCL     J
0068 IF X<Y
0069 STO     B
0070 CLEAR
0071 RCL     E
0072 RCL     J
0073 IF X≥Y
0074 STO     E
0075 RETURN
```

```
0076 LBL
---- 31
0078 CLEAR
0079 RCL     E
0080 RCL     B
0081 -
0082 1
0083 0
0084 0
0085 0
0086 0
0087 *
0088 INT
0089 STO     F
0090 RCL     E
0091 RCL     B
0092 -
0093 1
0094 0
0095 0
0096 0
0097 0
0098 0
0099 *
0100 STO     G
0101 1
0102 0
0103 ÷
0104 INT
0105 1
0106 0
0107 *
0108 STO     I
0109 RCL     G
0110 RCL     I
0111 -
0112 5
0113 IF X<Y
0114 GOTO    L25
0116 GOTO    L26
0118 LBL
---- 25
0120 RCL     F
0121 1
0122 +
0123 INT
0124 STO     F
0125 LBL
---- 26
0127 RCL     F
0128 1
0129 5
0130 IF X<Y
0131 GOTO    L52
0133 GOTO    L51
```

```
0135 LBL
---- 51
0137 CLEAR
0138 FIX     6
0140 4
0141 2
0142 STO     C
0143 1
0144 7
0145 0
0146 STO     H
0147 4
0148 STO     D
0149 FOR     C→HD
0150 RCL I   C
0152 STO     J
0153 STO     E
0154 IF 0
0155 GOTO    L98
0157 RCL     B
0158 -
0159 1
0160 0
0161 0
0162 0
0163 0
0164 *
0165 INT
0166 GOSUB   LX
0167 NEXT    C
0168 LBL
---- 00
0170 PRNTα
0172 *
0173 ENDα
0174 RETURN
0175 LBL
---- 01
0177 PRNTα
0179 *
0180 0
0181 ENDα
0182 RETURN
0183 LBL
---- 02
0185 PRNTα
0187 *
0188 0
0189 0
0190 ENDα
0191 RETURN
0192 LBL
---- 03
0194 PRNTα
0196 *
0197 0
0198 0
0199 0
0200 ENDα
0201 RETURN
0202 LBL
---- 04
0204 PRNTα
0206 *
0207 0
0208 0
0209 0
0210 0
0211 ENDα
0212 RETURN
0213 LBL
---- 05
0215 PRNTα
0217 *
0218 0
0219 0
0220 0
0221 0
0222 0
0223 ENDα
0224 RETURN
```

```
0225 LBL
---- 06
0227 PRNTα
0229 *
0230 0
0231 0
0232 0
0233 0
0234 0
0235 0
0236 ENDα
0237 RETURN
0238 LBL
---- 07
0240 PRNTα
0242 *
0243 0
0244 0
0245 0
0246 0
0247 0
0248 0
0249 0
0250 ENDα
0251 RETURN
0252 LBL
---- 08
0254 PRNTα
0256 *
0257 0
0258 0
0259 0
0260 0
0261 0
0262 0
0263 0
0264 0
0265 ENDα
0266 RETURN
0267 LBL
---- 09
0269 PRNTα
0271 *
0272 0
0273 0
0274 0
0275 0
0276 0
0277 0
0278 0
0279 0
0280 0
0281 ENDα
0282 RETURN
0283 LBL
---- 10
0285 PRNTα
0287 *
0288 0
0289 0
0290 0
0291 0
0292 0
0293 0
0294 0
0295 0
0296 0
0297 0
0298 ENDα
0299 RETURN
0300 LBL
---- 11
0302 PRNTα
0304 *
0305 0
0306 0
0307 0
0308 0
0309 0
0310 0
0311 0
0312 0
0313 0
0314 0
0315 0
0316 ENDα
0317 RETURN
0318 LBL
---- 12
0320 PRNTα
0322 *
0323 0
0324 0
0325 0
0326 0
0327 0
0328 0
0329 0
0330 0
0331 0
0332 0
0333 0
0334 0
0335 ENDα
0336 RETURN
```

```
0337 LBL
---- 13
0339 PRNTα
0341 *
0342 0
0343 0
0344 0
0345 0
0346 0
0347 0
0348 0
0349 0
0350 0
0351 0
0352 0
0353 0
0354 0
0355 ENDα
0356 RETURN
0357 LBL
---- 14
0359 PRNTα
0361 *
0362 0
0363 0
0364 0
0365 0
0366 0
0367 0
0368 0
0369 0
0370 0
0371 0
0372 0
0373 0
0374 0
0375 0
0376 ENDα
0377 RETURN
```

```
0378 LBL
---- 15
0380 PRNTα
0382 *
0383 0
0384 0
0385 0
0386 0
0387 0
0388 0
0389 0
0390 0
0391 0
0392 0
0393 0
0394 0
0395 0
0396 0
0397 0
0398 ENDα
0399 RETURN
0400 NOP
0401 LBL
---- 52
0403 CLEAR
0404 1
0405 7
0406 +⇌-
0407 LD&GO
0408 NOP
0409 LBL
---- 98
0411 1
0412 5
0413 +⇌-
0414 LD&GO
0415 END
```

- Label 52 -

This label loads File -17 into the computer.

Label 98

This label loads File -15 into the computer.

```
FILE    -15
TYPE     0
USED     418
MAX      1000

0000 NOP
0001 NOP
0002 CLRA→J
```

File -15 is basically identical to File -13 except that it analyzes the data taken and prints a histogram of the hole profile for the 90 degree axis.

```
0003 FIX      0
0005 1
0006 5
0007 +⇵-
0008 STO      R033
```

-15 is stored in Register 33.

```
0010 SPACE
0011 PRNT∝
0013 9
0014 0
0015
0016 D
0017 E
0018 G
0019 .
0020
0021 A
0022 L
0023 I
0024 G
0025 N
0026 M
0027 T
0028 END∝
```

The Message
'90 Deg. Alignmt" is printed.

```
0029 CLEAR
0030 FIX      6
0032 4
0033 3
0034 STO      A
0035 STO      C
0036 1
0037 7
0038 0
0039 STO      H
0040 4
0041 STO      D
0042 FOR      C→HD
0043 RCL  I   C
0045 IF  0
0046 GOTO     L31
0048 STO      J
0049 GOSUB    L50
0051 NEXT     C
```

```
0052 LBL
---- 50
0054 CLEAR
0055 RCL      B
0056 IF 0
0057 GOTO     L32
0059 GOTO     L33
0061 LBL
---- 32
0063 RCL      J
0064 STO      B
0065 LBL
---- 33
0067 CLEAR
0068 RCL      B
0069 RCL      J
0070 IF X<Y
0071 STO      B
0072 CLEAR
0073 RCL      E
0074 RCL      J
0075 IF X≥Y
0076 STO      E
0077 RETURN
0078 LBL
---- 31
0080 CLEAR
0081 RCL      E
0082 RCL      B
0083 -
0084 1
0085 0
0086 0
0087 0
0088 0
0089 *
0090 INT
0091 STO      F
0092 RCL      E
0093 RCL      B
0094 -
0095 1
0096 0
0097 0
0098 0
0099 0
0100 0
0101 *
0102 STO      G
0103 1
0104 0
0105 ÷
0106 INT
0107 1
0108 0
0109 *
0110 STO      I
0111 RCL      G
0112 RCL      I
0113 -
0114 5
0115 IF X<Y
0116 GOTO     L25
0118 GOTO     L26
0120 LBL
---- 25
0122 RCL      F
0123 1
0124 +
0125 INT
0126 STO      F
0127 LBL
---- 26
0129 RCL      F
0130 1
0131 5
0132 IF X<Y
0133 GOTO     L52
0135 GOTO     L51
```

```
0137 LBL
---- 51
0139 CLEAR
0140 FIX      6
0142 4
0143 3
0144 STO      C
0145 1
0146 7
0147 0
0148 STO      H
0149 4
0150 STO      D
0151 FOR      C→HD
0152 RCL  I   C
0154 STO      J
0155 STO      E
0156 IF 0
0157 GOTO     L98
0159 RCL      B
0160 -
0161 1
0162 0
0163 0
0164 0
0165 0
0166 *
0167 INT
0168 GOSUB    LX
0169 NEXT     C
0170 LBL
---- 00
0172 PRNTα
0174 *
0175 ENDα
0176 RETURN
0177 LBL
---- 01
0179 PRNTα
0181 *
0182 0
0183 ENDα
0184 RETURN
0185 LBL
---- 02
0187 PRNTα
0189 *
0190 0
0191 0
0192 ENDα
0193 RETURN
0194 LBL
---- 03
0196 PRNTα
0198 *
0199 0
0200 0
0201 0
0202 ENDα
0203 RETURN
0204 LBL
---- 04
0206 PRNTα
0208 *
0209 0
0210 0
0211 0
0212 0
0213 ENDα
0214 RETURN
0215 LBL
---- 05
0217 PRNTα
0219 *
0220 0
0221 0
0222 0
0223 0
0224 0
0225 ENDα
0226 RETURN
```

```
0227 LBL
---- 06
0229 PRNTα
0231 *
0232 0
0233 0
0234 0
0235 0
0236 0
0237 0
0238 ENDα
0239 RETURN
0240 LBL
---- 07
0242 PRNTα
0244 *
0245 0
0246 0
0247 0
0248 0
0249 0
0250 0
0251 0
0252 ENDα
0253 RETURN
0254 LBL
---- 08
0256 PRNTα
0258 *
0259 0
0260 0
0261 0
0262 0
0263 0
0264 0
0265 0
0266 0
0267 ENDα
0268 RETURN
0269 LBL
---- 09
0271 PRNTα
0273 *
0274 0
0275 0
0276 0
0277 0
0278 0
0279 0
0280 0
0281 0
0282 0
0283 ENDα
0284 RETURN
0285 LBL
---- 10
0287 PRNTα
0289 *
0290 0
0291 0
0292 0
0293 0
0294 0
0295 0
0296 0
0297 0
0298 0
0299 0
0300 ENDα
0301 RETURN
0302 LBL
---- 11
0304 PRNTα
0306 *
0307 0
0308 0
0309 0
0310 0
0311 0
0312 0
0313 0
0314 0
0315 0
0316 0
0317 0
0318 ENDα
0319 RETURN
0320 LBL
---- 12
0322 PRNTα
0324 *
0325 0
0326 0
0327 0
0328 0
0329 0
0330 0
0331 0
0332 0
0333 0
0334 0
0335 0
0336 0
0337 ENDα
0338 RETURN
```

```
0339 LBL
---- 13
0341 PRNTα
0343 *
0344 0
0345 0
0346 0
0347 0
0348 0
0349 0
0350 0
0351 0
0352 0
0353 0
0354 0
0355 0
0356 0
0357 ENDα
0358 RETURN
0359 LBL
---- 14
0361 PRNTα
0363 *
0364 0
0365 0
0366 0
0367 0
0368 0
0369 0
0370 0
0371 0
0372 0
0373 0
0374 0
0375 0
0376 0
0377 0
0378 ENDα
0379 RETURN
```

```
0380 LBL
---- 15
0382 PRNTα
0384 *
0385 0
0386 0
0387 0
0388 0
0389 0
0390 0
0391 0
0392 0
0393 0
0394 0
0395 0
0396 0
0397 0
0398 0
0399 0
0400 ENDα
0401 RETURN
0402 NOP
0403 LBL
---- 52
0405 CLEAR
0406 1
0407 7
0408 +÷-
0409 LD&GO
0410 NOP
0411 LBL
---- 98
0413 1
0414 6
0415 +÷-
0416 LD&GO
0417 END
```

-Label 52-
This label loads File -17 into the computer.

-Label 98-
This label loads File-16 into the computer.

```
FILE    -16
TYPE     0
USED     439
MAX      1000
```

File -16 is basically identical to File -13 except that it analyzes the data taken and prints a histogram of the hole profile for the 135 degree axis.

```
0000 NOP
0001 NOP
0002 CLRA+J
0003 FIX     0
0005 1
0006 6
0007 +÷-
0008 STO     R033
```

-16 is stored in Register 33.

```
0010 SPACE
0011 PRNT∝
0013 1
0014 3
0015 5
0016
0017 D
0018 E
0019 G
0020 .
0021
0022 A
0023 L
0024 I
0025 G
0026 N
0027 M
0028 T
0029 END∝
```

The Message "135 Deg. Alignmt" is printed.

```
0030 CLEAR
0031 FIX     6
0033 4
0034 4
0035 STO     A
0036 STO     C
0037 1
0038 7
0039 0
0040 STO     H
0041 4
0042 STO     D
0043 FOR     C+HD
0044 RCL  I  C
0046 IF 0
0047 GOTO    L31
0049 STO     J
0050 GOSUB   L50
0052 NEXT    C
```

```
0053 LBL
---- 50
0055 CLEAR
0056 RCL      B
0057 IF 0
0058 GOTO     L32
0060 GOTO     L33
0062 LBL
---- 32
0064 RCL      J
0065 STO      B
0066 LBL
---- 33
0068 CLEAR
0069 RCL      B
0070 RCL      J
0071 IF X<Y
0072 STO      B
0073 CLEAR
0074 RCL      E
0075 RCL      J
0076 IF X≥Y
0077 STO      E
0078 RETURN
0079 LBL
---- 31
0081 CLEAR
0082 RCL      E
0083 RCL      B
0084 -
0085 1
0086 0
0087 0
0088 0
0089 0
0090 *
0091 INT
0092 STO      F
0093 RCL      E
0094 RCL      B
0095 -
0096 1
0097 0
0098 0
0099 0
0100 0
0101 0
0102 *
0103 STO      G
0104 1
0105 0
0106 ÷
0107 INT
0108 1
0109 0
0110 *
0111 STO      I
0112 RCL      G
0113 RCL      I
0114 -
0115 5
0116 IF X<Y
0117 GOTO     L25
0119 GOTO     L26
0121 LBL
---- 25
0123 RCL      F
0124 1
0125 +
0126 INT
0127 STO      F
0128 LBL
---- 26
0130 RCL      F
0131 1
0132 5
0133 IF X<Y
0134 GOTO     L52
0136 GOTO     L51
```

```
0138 LBL
---- 51
0140 CLEAR
0141 FIX      6
0143 4
0144 4
0145 STO      C
0146 1
0147 7
0148 0
0149 STO      H
0150 4
0151 STO      D
0152 FOR      C→HD
0153 RCL  I   C
0155 STO      J
0156 STO      E
0157 IF  0
0158 GOTO     L98
0160 RCL      B
0161 -
0162 1
0163 0
0164 0
0165 0
0166 0
0167 *
0168 INT
0169 GOSUB    LX
0170 NEXT     C
0171 LBL
---- 00
0173 PRNTα
0175 *
0176 ENDα
0177 RETURN
0178 LBL
---- 01
0180 PRNTα
0182 *
0183 0
0184 ENDα
0185 RETURN
0186 LBL
---- 02
0188 PRNTα
0190 *
0191 0
0192 0
0193 ENDα
0194 RETURN
0195 LBL
---- 03
0197 PRNTα
0199 *
0200 0
0201 0
0202 0
0203 ENDα
0204 RETURN
0205 LBL
---- 04
0207 PRNTα
0209 *
0210 0
0211 0
0212 0
0213 0
0214 ENDα
0215 RETURN
0216 LBL
---- 05
0218 PRNTα
0220 *
0221 0
0222 0
0223 0
0224 0
0225 0
0226 ENDα
0227 RETURN
```

```
0228 LBL
---- 06
0230 PRNTα
0232 *
0233 0
0234 0
0235 0
0236 0
0237 0
0238 0
0239 ENDα
0240 RETURN
0241 LBL
---- 07
0243 PRNTα
0245 *
0246 0
0247 0
0248 0
0249 0
0250 0
0251 0
0252 0
0253 ENDα
0254 RETURN
0255 LBL
---- 08
0257 PRNTα
0259 *
0260 0
0261 0
0262 0
0263 0
0264 0
0265 0
0266 0
0267 0
0268 ENDα
0269 RETURN
0270 LBL
---- 09
0272 PRNTα
0274 *
0275 0
0276 0
0277 0
0278 0
0279 0
0280 0
0281 0
0282 0
0283 0
0284 ENDα
0285 RETURN
0286 LBL
---- 10
0288 PRNTα
0290 *
0291 0
0292 0
0293 0
0294 0
0295 0
0296 0
0297 0
0298 0
0299 0
0300 0
0301 ENDα
0302 RETURN
0303 LBL
---- 11
0305 PRNTα
0307 *
0308 0
0309 0
0310 0
0311 0
0312 0
0313 0
0314 0
0315 0
0316 0
0317 0
0318 0
0319 ENDα
0320 RETURN
0321 LBL
---- 12
0323 PRNTα
0325 *
0326 0
0327 0
0328 0
0329 0
0330 0
0331 0
0332 0
0333 0
0334 0
0335 0
0336 0
0337 0
0338 ENDα
0339 RETURN
```

File -16

```
0340 LBL
---- 13
0342 PRNTα
0344 *
0345 0
0346 0
0347 0
0348 0
0349 0
0350 0
0351 0
0352 0
0353 0
0354 0
0355 0
0356 0
0357 0
0358 ENDα
0359 RETURN
0360 LBL
---- 14
0362 PRNTα
0364 *
0365 0
0366 0
0367 0
0368 0
0369 0
0370 0
0371 0
0372 0
0373 0
0374 0
0375 0
0376 0
0377 0
0378 0
0379 ENDα
0380 RETURN
```

```
0381 LBL
---- 15
0383 PRNTα
0385 *
0386 0
0387 0
0388 0
0389 0
0390 0
0391 0
0392 0
0393 0
0394 0
0395 0
0396 0
0397 0
0398 0
0399 0
0400 0
0401 ENDα
0402 RETURN
0403 NOP
```

Label 52
File -17 is loaded into the computer

```
0404 LBL
---- 52
0406 CLEAR
0407 1
0408 7
0409 +÷-
0410 LD&GO
0411 NOP
0412 LBL
---- 98
0414 PRNTα
0416 *
0417
0418 *
0419
0420 *
0421
0422 *
0423
0424 *
0425
0426 *
0427
0428 *
0429
0430 *
0431
0432 ENDα
```

File -20 is loaded into the computer

```
0433 CLEAR
0434 2
0435 0
0436 +÷-
0437 LD&GO
0438 END
```

```
FILE    -17
TYPE     0
USED     271
MAX      1200

0000 NOP
0001 CLEAR
0002 FIX        6
0004 RCL        A
0005 STO        C
0006 1
0007 7
0008 0
0009 STO        H
0010 4
0011 STO        D
0012 FOR        C→HD
0013 RCL  I     C
0015 STO        J
0016 STO        E
0017 IF 0
0018 GOTO       L98
0020 RCL        B
0021 -
0022 1
0023 0
0024 0
0025 0
0026 0
0027 *
0028 INT
0029 STO        F
0030 RCL        E
0031 RCL        B
0032 -
0033 1
0034 0
0035 0
0036 0
0037 0
0038 0
0039 *
0040 STO        G
0041 1
0042 0
0043 ÷
0044 INT
0045 1
0046 0
0047 *
0048 STO        I
0049 RCL        G
0050 RCL        I
0051 -
0052 5
0053 IF X<Y
0054 GOTO       L25
0056 GOTO       L26
```

File -17 is addressed whenever the range of data for the hole profile exceeds .0015 inch. The result is that the profile printout is printed with X's instead of zeros. Each X represents one thousandth.

A fix 6 is programmed in to print the data to 6 significant places.

A C,D,H "For Next" loop is used to analyze the data.

Register A is recalled and stored in Register C. Register A contains the register number of the first data entry for whatever axis is being analyzed.

170 is stored in Register H.

4 is stored in Register D to recall indirectly the data stored in increments of 4.

The data taken by the "For Next" loop is stored in Registers E and J.

When it encounters an empty register (zero), label 98 is addressed.

Register B is recalled (the smallest data entry) and is subtracted from Register E. The difference is multiplied by 10,000, its integer is calculated and the result is stored in Register F.

Register B is subtracted from Register E. The difference is multiplied by 100,000 and stored in Register G.

This same value is divided by 10, its integer value is taken, and then it is multiplied by 10. This value is stored in Register I.

Register G is recalled.

Register I is recalled and is subtracted from Register G.

If the difference is more than 5, label 25 is addressed.

If the difference is 5 or less label 26 is addressed.

```
0058 LBL
---- 25
0060 RCL     F
0061 1
0062 +
0063 INT
0064 STO     F
0065 LBL
---- 26
0067 RCL     F
0068 INT
0069 1
0070 0
0071 IF X=Y
0072 GOTO    L41
0074 IF X≥Y
0075 GOTO    L40
0077 RCL     F
0078 2
0079 0
0080 IF X=Y
0081 GOTO    L42
0083 IF X≥Y
0084 GOTO    L41
0086 RCL     F
0087 3
0088 0
0089 IF X=Y
0090 GOTO    L43
0092 IF X≥Y
0093 GOTO    L42
0095 RCL     F
0096 4
0097 0
0098 IF X=Y
0099 GOTO    L44
0101 IF X≥Y
0102 GOTO    L43
0104 RCL     F
0105 5
0106 0
0107 IF X=Y
0108 GOTO    L45
0110 IF X≥Y
0111 GOTO    L44
0113 RCL     F
0114 6
0115 0
0116 IF X=Y
0117 GOTO    L46
0119 IF X≥Y
0120 GOTO    L45
```

Register F is recalled, incremented by 1 and stored in Register F. Label 26 is programmed in next.

-Label 26-

Register F is recalled, its integer value is calculated and it is compared to the number 10 (this number is equivalent to a .001 difference).

If the values equal, label 41 is addressed.

If the number 10 is equal to or greater than the number, label 40 is addressed.

If the number 10 is less than the number, register F is recalled and it is compared to the number 20.

If the values equal, label 42 is addressed.

If the number 20 is equal to or greater than register F, label 41 is addressed.

If the number 20 is less than register F, register F is recalled and compared to the number 30.

If the values equal, label 43 is addressed.

If the number 30 is equal to or greater than register F, label 42 is addressed.

If the number 30 is less than register F, register F is recalled and it is compared to the number 40.

If the values equal, label 44 is addressed.

If the number 40 is greater than register F, label 43 is addressed.

If the number 40 is less than register F, register F is recalled and it is compared to 50.

If the values equal, label 45 is addressed.

If the number 50 is greater than register F, label 44 is addressed.

If the number 50 is less than Register F, Register F is recalled and it is compared to the number 60.

If the values equal, label 46 is addressed.

If the number 60 is greater than Register F, label 45 is addressed.

```
0122 LBL
---- 40
0124 RCL     F
0125 FIX     0
0127 PRNTα
0129 *
0130 PRINT
0131 ENDα
0132 NEXT    C
0133 LBL
---- 41
0135 RCL     F
0136 1
0137 0
0138 -
0139 FIX     0
0141 PRNTα
0143 *
0144 X
0145 PRINT
0146 ENDα
0147 NEXT    C
0148 LBL
---- 42
0150 RCL     F
0151 2
0152 0
0153 -
0154 FIX     0
0156 PRNTα
0158 *
0159 X
0160 X
0161 PRINT
0162 ENDα
0163 NEXT    C
```

-Label 40-

Register F is recalled.

A fix 0 is programmed in to omit the decimal point of the number in Register F.

One asterisk is printed on the tape.

The number in Register F is printed on the other side of the histogram. This number shows how many tens of thousandths more the profile actually has without distorting the profile picture out of scale.

"Next C" returns the program to the "for next loop" (step 0013) for the next data reading to be analyzed.

-Label 41-

Register F is recalled.

10 is subtracted from Register F.

A fix 0 is programmed in to omit the decimal part of the difference.

One asterisk and one X are printed on the tape for the hole profile.

The difference number is printed on the other side of the tape to show how many tens of thousandths more the profile actually has without distorting the profile picture out of scale.

"Next C" returns the program to the "For Next" loop (Step 0013).

-Label 42-

Register F is recalled.

20 is subtracted from Register F.

A fix 0 is programmed in to omit the decimal part of the difference.

One asterisk and two X's are printed on the tape for the hole profile.

The difference number is printed on the other side of the tape to show how many tens of thousandths more the profile actually has without distorting the profile picture out of scale.

"Next C" returns the program to the "For Next" loop (step 0013).

```
0164 LBL
---- 43
0166 RCL     F
0167 3
0168 0
0169 -
0170 FIX     0
0172 PRNTα
0174 *
0175 X
0176 X
0177 X
0178 PRINT
0179 ENDα
0180 NEXT    C
0181 LBL
---- 44
0183 RCL     F
0184 4
0185 0
0186 -
0187 FIX     0
0189 PRNTα
0191 *
0192 X
0193 X
0194 X
0195 X
0196 PRINT
0197 ENDα
0198 NEXT    C
0199 LBL
---- 45
0201 RCL     F
0202 5
0203 0
0204 -
0205 FIX     0
0207 PRNTα
0209 *
0210 X
0211 X
0212 X
0213 X
0214 X
0215 PRINT
0216 ENDα
0217 NEXT    C
0218 NOP
```

-Label 43-

Register F is recalled.

30 is subtracted from Register F.

A fix 0 is programmed in to omit the decimal part of the difference.

One asterisk and three X's are printed on the tape for the hole profile.

The difference number is printed on the other side of the tape to show how many tens of thousandths more the profile actually has without distorting the profile picture out of scale.

"Next C" returns the program to the "For Next" loop (step 0013).

-Label 44-

Register F is recalled.

40 is subtracted from Register F.

A fix 0 is programmed in to omit the decimal part of the difference.

One asterisk and four zeros are printed on the tape for the hole profile.

The difference number is printed on the other side of the tape to show how many tens of thousandths more the profile actually has without distorting the profile picture out of scale. "Next C" returns the program to the "For Next" loop.

-Label 45-

Register F is recalled.

50 is subtracted from Register F.

A "Fix 0" is programmed in to omit the decimal part of the difference.

One asterisk and five X's are printed on the tape for the hole profile.

The difference number is printed on the other side of the tape to show how many tens of thousandths more the profile actually has without distorting the profile picture out of scale.

"Next "C" returns the program to the "For Next" loop (step 0013).

```
0219 LBL
---- 98
0221 CLEAR
0222 FIX      0
0224 RCL      R033
0226 1
0227 6
0228 +≑-
0229 IF X=Y
0230 GOTO     L99
0232 RCL      R033
0234 1
0235 -
0236 STO      R033
0238 CLEAR
0239 RCL      R033
0241 LD&GO
0242 LBL
---- 99
0244 PRNT∝
0246 *
0247
0248 *
0249
0250 *
0251
0252 *
0253
0254 *
0255
0256 *
0257
0258 *
0259
0260 *
0261 END∝
0262 0
0263 STO      R033
0265 CLEAR
0266 1
0267 8
0268 +≑-
0269 LD&GO
0270 END
```

-Label 98-

The stack is cleared.

A fix 0 is programmed in to omit the decimal part of the numbers being recalled.

Register 33 is recalled.

If Register 33 contains -16, label 99 is addressed.

Register 33 is recalled again.

One is subtracted from it and it is restored in Register 33.

The stack is cleared.

Register 33 is recalled.

The file corresponding to the number in Register 33 is loaded into the computer.

-Label 99-

A series of asterisks are printed along the tape to signify the end of the hole profile analysis.

A zero is stored in Register 33.

File -18 is loaded in to the computer

```
FILE    -18
TYPE     0
USED     116
MAX      1000
```

File -18 prints the header statement for the histogram for each hole.

```
0000 NOP
0001 SPACE
0002 SPACE
0003 SPACE
0004 FIX     0
0006 NOP
0007 PRNTα
0009 =
0010
0011 =
0012
0013 =
0014
0015 =
0016
0017 =
0018
0019 =
0020
0021 =
0022
0023 =
0024
0025 ENDα
```

```
= = = = = = = =
   HISTOGRAM
    OF DATA
  DISTRIBUTION
 FOR HOLE NO.  1

= = = = = = = =
```

Register 025 contains the hole no. being analyzed.

```
0026 RCL     R025
0028 PRNTα
0030
0031
0032
0033 H
0034 I
0035 S
0036 T
0037 O
0038 G
0039 R
0040 A
0041 M
0042 LINE
0043
0044
0045
0046
0047 O
0048 F
0049
0050 D
0051 A
0052 T
0053 A
```

File -18

```
0054 LINE
0055
0056
0057 D
0058 I
0059 S
0060 T
0061 R
0062 I
0063 B
0064 U
0065 T
0066 I
0067 O
0068 N
0069 LINE
0070
0071 F
0072 O
0073 R
0074
0075 H
0076 O
0077 L
0078 E
0079
0080 N
0081 O
0082 .
0083
0084 PRINT
0085 ENDα
0086 SPACE
0087 PRNTα
0089 =
0090
0091 =
0092
0093 =
0094
0095 =
0096
0097 =
0098
0099 =
0100
0101 =
0102
0103 =
0104
0105 ENDα
0106 FIX     6
0108 SPACE
0109 SPACE
0110 CLEAR
0111 1
0112 9
0113 +⇌-
0114 LD&GO
0115 END
```

This program loads file -19 into the computer (steps 0111 thru 0114).

```
FILE    -19
TYPE     0
USED     626
MAX      1000

0000 NOP
0001 PRNTα
0003 +
0004 ENDα
0005 CLRA→J
0006 FIX      6
0008 RCL      R011
0010 STO      B
0011 4
0012 1
0013 STO      A
0014 1
0015 7
0016 0
0017 STO      F
0018 FOR      A→F
0019 RCL  I   A
0021 IF  0
0022 GOTO     0034
0024 RCL      B
0025 RCL  I   A
0027 IF  X≥Y
0028 NEXT     A
0029 RCL      I
0030 1
0031 +
0032 STO      I
0033 NEXT     A
0034 RCL      I
0035 1
0036 5
0037 IF  X<Y
0038 GOTO     L30
0040 GOTO     0048
```

File -19 prints a histogram for each hole in the lot.

One plus sign is printed on the tape.

Registers A through J are cleared.

"Fix 6" is programmed in to print the data to six significant digits.

Register 11 (Lower Limit Tolerance) is recalled and is stored in Register B.

A "For Next" Loop is set up to check the data to see how many, if any, data entries are smaller than the lower limitl

41 is stored in Register A.

170 is stored in Register F.

Indirect Register A is recalled and compared to zero.

1 - If they equal, the program jumps to step 0034. Register I is recalled and compared to the number 15.

  a- If Register I is larger than 15, label 30 is addressed.

  b- If Register I equal or smaller than 15, the program jumps to step 48. Here Register I is recalled (counter) and the number in Register I addresses a GoSub label of the same number. These various sub labels print one plus sign and different number of asterisks depending on the counter number in Register I. The program then returns to step 50.

2 - If Register A does not equal zero, Register B is recalled. Register Indirect A is recalled and compared to Register B.

If Register Indirect A is equal to or greater than Register B, the "For Next" Loop recycles and the next data entry is analyzed.

If Register Indirect A is smaller than Register B, Register I is recalled, one is added to it and it is restored in Register I. Then the "For Next" Loop is recycled for the next data entry to be analyzed.

```
0042 LBL
---- 30
0044 GOSUB   L60
0046 GOTO    0050
0048 RCL     I
0049 GOSUB   LX
0050 RCL     R011
0052 PRNT∝
0054 +
0055 LINE
0056 L
0057 .
0058 L
0059 .
0060 =
0061 V
0062 V
0063 =
0064 PRINT
0065 END∝
0066 CLRA→J
0067 RCL     R011
0069 1
0070 0
0071 0
0072 0
0073 0
0074 *
0075 INT
0076 STO     A
0077 RCL     R012
0079 1
0080 0
0081 0
0082 0
0083 0
0084 *
0085 INT
0086 1
0087 +
0088 STO     F
0089 FOR     A→F
0090 RCL     A
0091 RCL     F
0092 IF X=Y
0093 GOTO    L56
0095 4
0096 1
0097 STO     B
0098 1
0099 7
0100 0
0101 STO     G
0102 FOR     B→G
0103 RCL I   B
0105 IF 0
0106 GOTO    L55
```

-Label 30-

Go Sub Label 60 is addressed.

Label 60 prints one plus sign, 14 asterisks and one zero on a line. The zero signifies there are more than 15 data entries of a certain value.

The program returns to step 0046 which instructs the program to go to step 0050.

At step 0050 Register 11 is recalled.

Here one plus is printed on the tape.

On a second line "L.L. = VV = is printed on the tape along with the value in Register 11.

Registers A through J are cleared.

Register 11 is recalled.

Register 11 is multiplied by 10,000, its integer is calculated and it is stored in Register A.

Register 12 (upper limit tolerance) is recalled.

Register 12 is multiplied by 10,000, and its integer is calculated,

1 is added to this number and it is stored in Register F.

The A F "For Next" Loop is set up to keep track of the value of the dimension diameter being analyzed.

Register A is recalled.

Register F is recalled and compared to Register A.

If they equal, label 56 is addressed.

If they don't equal, the program jumps to another "For Next" loop.

41 is stored in Register B.

170 is stored in Register G.

This "For Next" Loop goes through all the data for the hole being analyzed counting the number of data entries that are equal to the value in Register A of the first "For Next" Loop.

Register Indirect B is recalled.

It is equals zero, label 55 is addressed.

```
0108 1
0109 0
0110 0
0111 0
0112 0
0113 0
0114 *
0115 INT
0116 STO     R000
```

If Indirect Register B is not equal to zero, it is multiplied by 100,000, its integer is calculated and it is stored in Register 000.

```
0118 RCL I   B
0120 1
0121 0
0122 0
0123 0
0124 0
0125 *
0126 INT
```

Indirect Register B is recalled, it is multiplied by 10,000 and its integer is calculated.

```
0127 1
0128 0
0129 *
0130 STO     R001
```

This number is multiplied by 10 and stored in Register 01.

```
0132 RCL     R000
```

Register 00 is recalled.

```
0134 RCL     R001
0136 -
```

Register 01 is recalled and subtracted from Register 00.

```
0137 5
0138 IF X≥Y
0139 GOTO    L49
```

If the difference is less than or equal to 5, label 49 is addressed.

```
0141 RCL     R001
0143 1
0144 0
0145 +
0146 STO     R001
0148 LBL
---- 49
```

If the difference is greater than 5, Register 01 is recalled, 10 is added ot it and it is restored in Register 01. Label 49 is programmed in next.

-Label 49-

```
0150 RCL     R001
0152 1
0153 0
0154 ÷
```

Register 01 is recalled and divided by 10.

```
0155 RCL     A
0156 IF X=Y
```

Register A is recalled and compared to the above number.

```
0157 GOTO    L54
```

If they equal, label 54 is addressed.

```
0159 NEXT    B
```

If they don't dequal, the B-G "For Next" Loop recycles to the next data entry.

-Label 54-

```
0218 LBL
---- 54
0220 RCL     I
```

Register I is recalled.

```
0221 1
0222 +
0223 STO     I
```

1 is added to it and it is restored in Register I.

```
0224 NEXT    B
```

The B-G "For Next" Loop is recycled for the next data entry.

```
0225 LBL
---- 55
0227 GOSUB  E


0160 LBL
---- E
0162 RCL    A
0163 1
0164 0
0165 0
0166 0
0167 0
0168 ÷
0169 STO    R000
0171 RCL    R011
0173 IF X=Y
0174 RETURN
0175 RCL    R000
0177 RCL    R012
0179 IF X=Y
0180 RETURN
0181 RCL    A
0182 1
0183 +
0184 1
0185 0
0186 ÷
0187 INT
0188 1
0189 0
0190 *
0191 STO    R000
0193 RCL    A
0194 -
0195 IF 0
0196 GOTO   F
0198 RETURN
0199 LBL
---- F
0201 RCL    A
0202 1
0203 0
0204 0
0205 0
0206 0
0207 ÷
0208 PRNTα
0210 O
0211 =
0212 V
0213 V
0214 =
0215 PRINT
0216 ENDα
0217 RETURN
```

-Label 55-

Go Sub Level E is addressed.

-Label E-

Register A is recalled.

It is divided by 10,000 and storea in Register 00.

Register 11 is recalled and is compared to Register 00.

If they equal, the program returns to Step 229.

If they don't equal, Registers 00 and 12 are recalled and compared.

A - If they equal, the program returns to Step 229.

B - If they don't equal, Register A is recalled and 1 is added to it.

It is divided by 10 and its integer is calculated.

This number is multiplied by 10 and stored in Register 00.

Register A is recalled and subtracted from Register 00.

a - If there is no difference, label F is addressed.

b - If there is a difference, the program returns to step 229.

-Label F-

Register A is recalled.

It is divided by 10,000.

The message "O = VV =" is printed along with the above number.

The program returns to step 229.

```
0229 RCL     I
0230 1
0231 5
0232 IF X<Y
0233 GOTO    C
0235 RCL     I
0236 GOSUB   LX
0237 0
0238 STO     I
0239 NEXT    A
0240 LBL
---- C
0242 GOSUB   L60
0244 0
0245 STO     I
0246 NEXT    A
0247 LBL
---- 56
0249 RCL     R012
0251 PRNTα
0253 U
0254 .
0255 L
0256 .
0257 =
0258 *
0259 *
0260 =
0261 PRINT
0262 ENDα
0263 PRNTα
0265 +
0266 ENDα
```

Register I is recalled and compared to the number 15.

If Register I is 15 or greater, label C is addressed.

If Register I is less than 15, Register I is recalled and it addresses a GoSub label of the same number.

This label number ranging from 0 to 15 prints one plus sign, and varying numbers of asterisks to show how many data entries are of a certain value.

Zero is stored in Register I and the A-F "For Next" Loop is recycled for the next dimension analysis.

-Label C-

Go Sub label is addressed. (Label 60 prints one plus sign, 14 asterisks and one zero on a line. The zero signifies there are more than 15 data entries of a certain diameter).

0 is stored in Register I.

"Next A" recycles the A-F "For Next" Loop for the next dimension analysis.

-Label 56-

Register 12 (upper limit tolerance) is recalled.

The message "U.L. = ** =" is printed along with the contents of Register 12.

One plus sign is printed on the next line.

```
0267 CLRA→J
0268 RCL     R012
0270 .
0271 0
0272 0
0273 0
0274 1
0275 +
0276 STO     B
0277 4
0278 1
0279 STO     A
0280 1
0281 7
0282 0
0283 STO     F
0284 FOR     A→F
0285 RCL 1   A
0287 IF 0
0288 GOTO    L59
0290 RCL     B
0291 IF X<Y
0292 GOTO    L58
0294 NEXT    A
0295 LBL
---- 58
0297 RCL     I
0298 1
0299 +
0300 STO     I
0301 NEXT    A
0302 LBL
---- 59
0304 RCL     I
0305 1
0306 5
0307 IF X<Y
0308 GOTO    D
0310 RCL     I
0311 GOSUB   LX
0312 GOTO    0318
```

Registers A through J are cleared.

Register 12 is recalled.

:0001 is added to Register 12 and the total is stored in Register B.

A. A F "For Next" Loop is set up to check the data for any entries larger than the upper limit tolerance.

41 is stored in Register A.

170 is stored in Register F.

Indirect Register A is recalled and compared to zero.

1 - If they equal, label 59 is addressed.

2 - If they don't equal, Register B is recalled and the two numbers are compared.

a - If Register Indirect A is larger than Register B, label 58 is addressed

b - If Register Indirect A is smaller than Register B, the "For Next" Loop is recycled for the next data entry.

-Label 58-

Register I is recalled.

One is added to it and it is restored in Register I.

"Next A" recycles the A-F "For Next" Loop for the next data entry.

-Label 59-

Register I is recalled and compared to the number 15.

If Register I is larger than 15, label D is addressed.

If Register I is equal to or less than 15, Register I is recalled.

A GoSub routine is addressed by the number in Register I.

The program jumps to step 0318.

```
0314 LBL
---- D
0316 GOSUB  L60
0318 PRNTα
0320 +
0321 ENDα
0322 PRNTα
0324
0325
0326 +
0327
0328 =
0329
0330 .
0331 0
0332 0
0333 0
0334 1
0335
0336 I
0337 N
0338 C
0339 H
0340 ENDα
0341 ENDα
0342 PRNTα
0344 *
0345
0346 *
0347
0348 *
0349
0350 *
0351
0352 *
0353
0354 *
0355
0356 *
0357
0358 *
0359
0360 ENDα
0361 GOTO   L99
0363 NOP
```

-Label D-

GoSub Label 60 is addressed.

Label 60 prints one plus sign, 14 asterisks and one zero on a line. The zero signifies there are more than 15 data entries of a certain diameter.

One plus sign is printed.

The message
"X = .0001 inch" is printed on the tape.

A line of asterisks is printed on the tape to show the histogram analysis is completed.

Label 99 is addressed.

```
0364 LBL
---- 00
0366 PRNT∝
0368 +
0369 END∝
0370 RETURN
0371 LBL
---- 01
0373 PRNT∝
0375 +
0376 *
0377 END∝
0378 RETURN
0379 LBL
---- 02
0381 PRNT∝
0383 +
0384 *
0385 *
0386 END∝
0387 RETURN
0388 LBL
---- 03
0390 PRNT∝
0392 +
0393 *
0394 *
0395 *
0396 END∝
0397 RETURN
0398 LBL
---- 04
0400 PRNT∝
0402 +
0403 *
0404 *
0405 *
0406 *
0407 END∝
0408 RETURN
0409 LBL
---- 05
0411 PRNT∝
0413 +
0414 *
0415 *
0416 *
0417 *
0418 *
0419 END∝
0420 RETURN
0421 LBL
---- 06
0423 PRNT∝
0425 +
0426 *
0427 *
0428 *
0429 *
0430 *
0431 *
0432 END∝
0433 RETURN
0434 LBL
---- 07
0436 PRNT∝
0438 +
0439 *
0440 *
0441 *
0442 *
0443 *
0444 *
0445 *
0446 END∝
0447 RETURN
0448 LBL
---- 08
0450 PRNT∝
0452 +
0453 *
0454 *
0455 *
0456 *
0457 *
0458 *
0459 *
0460 *
0461 END∝
0462 RETURN
0463 LBL
---- 09
0465 PRNT∝
0467 +
0468 *
0469 *
0470 *
0471 *
0472 *
0473 *
0474 *
0475 *
0476 *
0477 END∝
0478 RETURN
```

```
0479 LBL
---- 10
0481 PRNTα
0483 +
0484 *
0485 *
0486 *
0487 *
0488 *
0489 *
0490 *
0491 *
0492 *
0493 *
0494 ENDα
0495 RETURN
0496 LBL
---- 11
0498 PRNTα
0500 +
0501 *
0502 *
0503 *
0504 *
0505 *
0506 *
0507 *
0508 *
0509 *
0510 *
0511 *
0512 ENDα
0513 RETURN
0514 LBL
---- 12
0516 PRNTα
0518 +
0519 *
0520 *
0521 *
0522 *
0523 *
0524 *
0525 *
0526 *
0527 *
0528 *
0529 *
0530 *
0531 ENDα
0532 RETURN
0533 LBL
---- 13
0535 PRNTα
0537 +
0538 *
0539 *
0540 *
0541 *
0542 *
0543 *
0544 *
0545 *
0546 *
0547 *
0548 *
0549 *
0550 *
0551 ENDα
0552 RETURN
0553 LBL
---- 14
0555 PRNTα
0557 +
0558 *
0559 *
0560 *
0561 *
0562 *
0563 *
0564 *
0565 *
0566 *
0567 *
0568 *
0569 *
0570 *
0571 *
0572 ENDα
0573 RETURN
```

```
0574 LBL
---- 15
0576 PRNTα
0578 +
0579 *
0580 *
0581 *
0582 *
0583 *
0584 *
0585 *
0586 *
0587 *
0588 *
0589 *
0590 *
0591 *
0592 *
0593 *
0594 ENDα
0595 RETURN
0596 LBL
---- 60
0598 PRNTα
0600 +
0601 *
0602 *
0603 *
0604 *
0605 *
0606 *
0607 *
0608 *
0609 *
0610 *
0611 *
0612 *
0613 *
0614 *
0615 O
0616 ENDα
0617 RETURN
0618 LBL
---- 99
0620 CLEfn
0621 2
0622 0
0623 +≑-
0624 LD&GO
0625 END
```

-Label 99-

File -20 is loaded into the computer.

```
FILE   -20
TYPE    0
USED    111
MAX     1000

0000 NOP
0001 NOP
0002 SPACE
0003 SPACE
0004 SPACE
0005 RCL       R003
0007 2
0008 IF X=Y
0009 GOTO      L99
```

Register 3 is recalled and compared to the number 2.

If they equal, label 99 is addressed.

```
0011 PRNTα
0013 I
0014 N
0015 S
0016 E
0017 R
0018 T
0019
0020 D
0021 A
0022 T
0023 A
0024
0025 T
0026 A
0027 P
0028 E
0029 ENDα
0030 STOP
0031 SPACE
0032 CLEAR
0033 FIX       0
0035 RCL       R025
0037 1
0038 +
```

If they don't equal, the message "Insert Data Tape" is printed. With the Data Tape now in the Computer, Register 25 is recalled and 1 is added to it.

```
0039 PRNTα
0041 N
0042 E
0043 X
0044 T
0045
0046 H
0047 O
0048 L
0049 E
0050
0051 PRINT
0052 ENDα
```

The message "Next Hole" is printed along with the above number.

File -20

```
0053 CLRA→J
0054 RCL      R025
0056 1
0057 +
0058 STO      A
0059 0
0060 #REGS
0061 CLEAR
0062 1
0063 7
0064 0
0065 #REGS
0066 RCL      A
0067 STO      R025
0069 CLX
0070 FIX      0
0072 1
0073 7
0074 0
0075 #REGS
0076 0
0077 0
0078 ENTER↑
0079 RCL      R025
0081 LOAD
0082 CLRA→J
0083 SPACE
0084 PRNTα
0086 I
0087 N
0088 S
0089 E
0090 R
0091 T
0092
0093 P
0094 R
0095 G
0096 M
0097
0098 T
0099 A
0100 P
0101 E
0102 ENDα
0103 STOP
0104 CLEAR
0105 8
0106 +⇌-
0107 LD&GO
0108 LBL
---- 99
0110 END
```

Register A through J are cleared.

Register 25 is recalled. 1 is added to it and it is stored in Register A.

"0#REGS" clears all memory registers.

"Clear" clears the register stack.

"170#REGS" opens up 170 registers for data storage.

Register A is recalled and is stored in Register 25.

"CLX" clears the X Register in the stack.

Fix 0 drops all the decimal parts of the numbers being programmed.

Steps 0072 throgh 0081 load the next file into the Computer to repeat the individual hole analysis with the next hole.

The message "Insert PRGM Tape" is printed on the tape.

With the program tape in the Computer, File -8 is loaded into the Computer.

```
FILE     -21
TYPE      0
USED      373
MAX       1000

0000 NOP
0001 NOP
0002 PRNTα
0004 I
0005 N
0006 S
0007 E
0008 R
0009 T
0010
0011 D
0012 A
0013 T
0014 A
0015
0016 T
0017 A
0018 P
0019 E
0020 ENDα
0021 SPACE
0022 PRNTα
0024 I
0025 N
0026 S
0027 E
0028 R
0029 T
0030
0031 P
0032 R
0033 G
0034 M
0035
0036 T
0037 A
0038 P
0039 E
0040 A
0041 F
0042 T
0043 E
0044 R
0045
0046 H
0047 E
0048 A
0049 D
0050 E
0051 R
0052
0053 I
0054 S
0055 LINE
0056 P
0057 R
0058 I
0059 N
0060 T
0061 E
0062 D
0063 ENDα
0064 SPACE
0065 SPACE
0066 STOP
```

Steps 0000 through 0066 print the message shown below.

```
INSERT DATA TAPE

INSERT PRGM TAPE
AFTER HEADER IS
PRINTED
```

Steps 0067 through 0173 print the message shown below.

```
0067 PRNTα
0069 =
0070 =
0071 =
0072 =
0073 =
0074 =
0075 =
0076 =
0077 =
0078 =
0079 =
0080 =
0081 =
0082 =
0083 =
0084 =
0085 ENDα
0086 SPACE
0087 PRNTα
0089 .
0090
0091
0092
0093 E
0094 X
0095 E
0096 C
0097 U
0098 T
0099 I
0100 V
0101 E
0102
0103
0104 .
0105 LINE
0106 .
0107
0108
0109
0110
0111 S
0112 U
0113 M
0114 M
0115 A
0116 R
0117 Y
0118
0119
0120
0121 .
0122 .
0123
0124
0125
0126 H
0127 I
0128 S
0129 T
0130 O
0131 G
0132 R
0133 A
0134 M
0135
0136
0137 .
0138 .
0139
0140 D
0141 I
0142 S
0143 T
0144 R
0145 I
0146 B
0147 U
0148 T
0149 I
0150 O
0151 N
0152
0153 .
0154 LINE
0155 =
0156 =
0157 =
0158 =
0159 =
0160 =
0161 =
0162 =
0163 =
0164 =
0165 =
0166 =
0167 =
0168 =
0169 =
0170 =
0171 ENDα
0172 SPACE
0173 SPACE
```

```
================

.   EXECUTIVE   .

.    SUMMARY    .
.   HISTOGRAM   .
. DISTRIBUTION  .

================
```

Label A is programmed in next

File -21

```
0174 LBL
---- A
0176 1
0177 7
0178 0
0179 #REGS
0180 NOP
0181 CLRA→J
0182 CLX
0183 FIX      0
0185 1
0186 7
0187 0
0188 #REGS
0189 0
0190 0
0191 ENTER↑
0192 2
0193 1
0194 +≠-
0195 LOAD
0196 RCL      R017
0198 PRNTα
0200 D
0201 A
0202 T
0203 A
0204
0205 S
0206 O
0207 U
0208 R
0209 C
0210 E
0211
0212 PRINT
0213 ENDα
0214 RCL      R015
0216 PRNTα
0218 D
0219 A
0220 T
0221 A
0222
0223 L
0224 O
0225 T
0226
0227 PRINT
0228 ENDα
0229 PRNTα
0231
0232
0233
0234
0235
0236
0237 *
0238 *
0239 *
0240 ENDα
```

File -21 is written primarily to scan all the data files to pick out the lowest and highest reading for each hole in the lot. This data is used here to analyze an executive summary histogram for each lot.

-Label A-

170 registers are opened for data storage.

Registers A through J are cleared.

File -21 of the data tape is loaded into the computer.

Register 17 is recalled (data source) and printed.

Register 15 is recalled (data lot) and printed.

The message printed on the tape is shown below.

```
DATA SOURCE     0
DATA LOT        0
      ***
```

File -21

```
0241 2
0242 1
0243 +⇌-
0244 STO     R004
0246 4
0247 0
0248 STO     G
0249 GOTO    C
0251 SPACE
0252 LBL
---- B
0254 CLEAR
0255 FIX     0
0257 1
0258 7
0259 0
0260 #REGS
0261 0
0262 0
0263 ENTER↑
0264 RCL     R004
0266 LOAD
0267 LBL
---- C
0269 RCL     R029
0271 IF -
0272 STO     R004
0274 FIX     6
0276 RCL     G
0277 1
0278 +
0279 STO     G
0280 RCL     R014
0282 FIX     0
0284 STO I   G
0286 RCL     G
0287 1
0288 +
0289 STO     G
0290 RCL     R018
0292 STO I   G
0294 RCL     R004
0296 1
0297 -
0298 STO     R004
0300 5
0301 0
0302 +⇌-
0303 IF X=Y
0304 GOTO    L50
0306 RCL     R004
0308 IDENT
0309 ROLL↓
0310 ROLL↓
0311 ROLL↓
0312 5
0313 IF X=Y
0314 GOTO    L50
0316 GOTO    B
```

-21 is stored in register 04.

40 is stored in register G.

Label C is addressed.

-Label B-

Register 04 is recalled.

The file with that number is loaded into the computer.

-Label C-

"Fix 6" sets up the data entries to six significant digits.

Register G is recalled.

1 is added to it and it is restored in Register G.

Register 14 (highest reading) is recalled.

It is stored indirectly in register G.

Register G is recalled.

1 is added to it and it is restored in register G.

Register 18 (lowest reading) is recalled.

It is stored indirectly in register G.

Register 04 is recalled.

1 is subtracted from it and it is restored in register 04.

This number is compared to a -50.

If they equal, label 50 is addressed.

If they don't equal, register 04 is recalled.

The file with this number is identified and its file type is compared to the number 5.

If they equal, label 50 is addressed.

If they don't equal, label B is addressed.

```
0318 LBL
---- 50
0320 2
0321 STO     R003
0323 FIX     0
0325 RCL     R004
0327 +/-
0328 2
0329 1
0330 -
0331 PRNTα
0333 PRINT
0334
0335 H
0336 O
0337 L
0338 E
0339
0340 L
0341 O
0342 T
0343
0344
0345
0346 ENDα
0347 PRNTα
0349 =
0350 =
0351 =
0352 =
0353 =
0354 =
0355 =
0356 =
0357 =
0358 =
0359 =
0360 =
0361 =
0362 =
0363 =
0364 =
0365 ENDα
0366 STOP
0367 CLEAR
0368 1
0369 9
0370 +/-
0371 LD&GO
0372 END
```

-Label 50-

2 is stored in register 03.

"Fix 0" drops the decimal portion of the following numbers.

Register 04 is recalled.

-21 is subtracted from it.

This number shows how many holes are in the lot and is printed as such.

File -19 is loaded into the computer to do the actual histogram layout for the summary. (See file -19).

```
FILE    -22
TYPE     0
USED     869
MAX      1000

0000 NOP
0001 NOP
0002 PRNTα
0004 I
0005 N
0006 S
0007 E
0008 R
0009 T
0010
0011 D
0012 A
0013 T
0014 A
0015
0016 T
0017 A
0018 P
0019 E
0020 ENDα
0021 STOP
0022 SPACE
0023 FIX      0
0025 PRNTα
0027 H
0028 O
0029 L
0030 E
0031
0032 N
0033 O
0034 .
0035 ?
0036
0037 ENDα
0038 STOP
0039 PRINT
0040 2
0041 0
0042 +
0043 +÷-
0044 STO      R004
0046 CLRA→J
0047 #REGS
0048 CLX
0049 FIX      0
0051 3
0052 5
0053 #REGS
0054 0
0055 0
0056 ENTER↑
0057 RCL      R004
0059 LOAD
0060 SPACE
```

The message
"Insert Data Tape" is printed.

With the data tape in the computer, the machine asks for the hole number.

The hole number gets printed on the tape.

20 is added to the hole number and its sign is inverted to a negative number.

This number is stored in register 4.

Registers A through J are cleared.

"# Regs" programmed alone open up zero registers for storage.

Register X of the stack is cleared.

"Fix 0" removes the decimal part of the following numbers.

Register 4 is recalled and the file with that number is loaded into the computer.

```
0061 RCL     R015
0063 PRNTα
0065 .
0066
0067 .
0068
0069 .
0070
0071 .
0072
0073 .
0074
0075 .
0076
0077 .
0078
0079 .
0080 .
0081 LINE
0082 .
0083
0084
0085 E
0086 X
0087 E
0088 C
0089 U
0090 T
0091 I
0092 V
0093 E
0094
0095
0096
0097 .
0098 LINE
0099 .
0100
0101
0102
0103 S
0104 U
0105 M
0106 M
0107 A
0108 R
0109 Y
0110
0111
0112
0113
0114 .
0115 .
0116
0117
0118 -
0119 B
0120 Y
0121
0122 H
0123 O
0124 L
0125 E
0126 -
0127
0128
0129
0130 .
0131 .
0132
0133
0134
0135
0136
0137 F
0138 O
0139 R
0140
0141
0142
0143
0144
0145
0146 .
0147 .
0148
0149
0150
0151
0152
0153 L
0154 O
0155 T
0156
0157 PRINT
0158
0159
0160
0161
0162 .
0163 ENDα
```

Steps 0061 through 0203 print the message below.

```
. . . . . . . . ..

.   EXECUTIVE   .

.    SUMMARY    .
.   -BY HOLE-   .
.      FOR      .
.     LOT 11
.
.DATA SOURCE 94.
* * * * * * * *
```

Registers 15 (Lot No.) is recalled and printed.

```
0164 RCL    R017
0166 PRNT∝
0168 .
0169 D
0170 A
0171 T
0172 A
0173
0174 S
0175 O
0176 U
0177 R
0178 C
0179 E
0180
0181 PRINT
0182 .
0183 END∝
0184 PRNT∝
0186 *
0187
0188 *
0189
0190 *
0191
0192 *
0193
0194 *
0195
0196 *
0197
0198 *
0199
0200 *
0201
0202 END∝
0203 SPACE
0204 GOTO   C
```

Register 17 (data source) is recalled and printed.

Label C is addressed.

```
0206 LBL
---- B
0208 CLX
0209 FIX     0
0211 3
0212 5
0213 #REGS
0214 0
0215 0
0216 ENTER↑
0217 RCL     R004
0219 LOAD
0220 LBL
---- C
0222 RCL     R025
0224 PRNTα
0226 H
0227 O
0228 L
0229 E
0230
0231 N
0232 O
0233 .
0234
0235 PRINT
0236 ENDα
0237 PRNTα
0239 =
0240
0241 =
0242
0243 =
0244
0245 =
0246
0247 =
0248
0249 =
0250
0251 =
0252
0253 =
0254
0255 ENDα
```

-Label B-

"Fix 0" drops the decimal part of the following numbers.

Register 4 is recalled, and the file with that number is loaded into the computer.

```
0256 RCL     R013
0258 PRNTα
0260 PRINT
0261
0262
0263 D
0264 A
0265 T
0266 A
0267
0268 E
0269 N
0270 T
0271 R
0272 I
0273 E
0274 S
0275 ENDα
0276 PRNTα
0278 =
0279
0280 =
0281
0282 =
0283
0284 =
0285
0286 =
0287
0288 =
0289
0290 =
0291
0292 =
0293
0294 ENDα
```

-Label C-

This label prints the message below.

```
HOLE NO.        1
= = = = = = = =
20  DATA ENTRIES
= = = = = = = =
```

Register 25 (Hole No.) is recalled and printed.

Register 13 (No. of data entries) is recalled and printed.

Steps 0296 through 0370 print the message below.

```
0295 SPACE
0296 PRNTα
0298 H
0299 O
0300 L
0301 E
0302
0303 S
0304 I
0305 Z
0306 E
0307 *
0308 ENDα
0309 PRNTα
0311
0312
0313 U
0314 P
0315 P
0316 E
0317 R
0318
0319 L
0320 I
0321 M
0322 I
0323 T
0324 =
0325 ENDα
0326 FIX     6
0328 RCL     R012
0330 PRINT
0331 PRNTα
0333
0334
0335 L
0336 O
0337 W
0338 E
0339 R
0340
0341 L
0342 I
0343 M
0344 I
0345 T
0346 =
0347 ENDα
0348 RCL     R011
0350 PRINT
0351 PRNTα
0353 =
0354
0355 =
0356
0357 =
0358
0359 =
0360
0361 =
0362
0363 =
0364
0365 =
0366
0367 =
0368
0369 EN
0370 SPACE
```

```
HOLE SIZE*
  UPPER LIMIT=
    0.315000
  LOWER LIMIT=
    0.312000
= = = = = = = =
```

"Fix 6" sets the data to six significant digits.

Register 12 (upper limit) is recalled and printed.

Register 11 (lower limit) is recalled and printed.

Steps 0371 through 0437 print the message below.

```
0371 PRNTα
0373 H
0374 I
0375 G
0376 H
0377 E
0378 S
0379 T
0380
0381 R
0382 E
0383 A
0384 D
0385 I
0386 N
0387 G
0388 =
0389 ENDα
0390 RCL      R014
0392 PRINT
0393 PRNTα
0395
0396
0397
0398
0399
0400
0401 *
0402 *
0403 *
0404 ENDα
0405 PRNTα
0407 L
0408 O
0409 W
0410 E
0411 S
0412 T
0413
0414 R
0415 E
0416 A
0417 D
0418 I
0419 N
0420 G
0421 =
0422 ENDα
0423 RCL      R018
0425 PRINT
0426 PRNTα
0428
0429
0430
0431
0432
0433
0434 *
0435 *
0436 *
0437 ENDα
```

```
HIGHEST READING=
    0.313391
       ***
LOWEST READING=
    0.313090
       ***
```

Register 14 (highest reading) is recalled and printed.

Register 18 (lowest reading) is recalled and printed.

```
0438 PRNTα
0440 M
0441 A
0442 X
0443 .
0444
0445 O
0446 V
0447 E
0448 R
0449 S
0450 I
0451 Z
0452 E
0453 =
0454 ENDα
0455 RCL     R014
0457 RCL     R012
0459 -
0460 IF -
0461 0
0462 PRNTα
0464
0465
0466
0467
0468 +
0469 +
0470 +
0471 +
0472 PRINT
0473 ENDα
0474 PRNTα
0476
0477
0478
0479
0480
0481
0482 *
0483 *
0484 *
0485 ENDα
```

```
0486 PRNTα
0488 M
0489 A
0490 X
0491 .
0492
0493 U
0494 N
0495 D
0496 E
0497 R
0498 S
0499 I
0500 Z
0501 E
0502 =
0503 ENDα
0504 RCL     R011
0506 RCL     R018
0508 -
0509 IF -
0510 0
0511 PRNTα
0513
0514
0515
0516
0517 -
0518 -
0519 -
0520 -
0521 PRINT
0522 ENDα
0523 PRNTα
0525 =
0526
0527 =
0528
0529 =
0530
0531 =
0532
0533 =
0534
0535 =
0536
0537 =
0538
0539 =
0540
0541 ENDα
```

Steps 0438 through 0541 print the message below.

```
MAX. OVERSIZE=
    ++++0.000000
       ***
MAX. UNDERSIZE=
    ----0.000000
= = = = = = = =
```

Register 14 (highest reading) is recalled.

Register 12 (upper limit tolerance) is recalled and subtracted from register 14.

If the answer is negative, zeros appear in the printout with 4 plus signs.

If the answer is positive, it is printed along with 4 plus signs.

Register 11 (lower limit tolerance) is recalled.

Register 18 is recalled, and subtracted from register 11.

If the answer is negative, zeros are printed on the tape with 4 minues signs.

If the answer is positive, it is printed on the tape with 4 minus signs.

```
0542 SPACE
0543 PRNTα
0545 R
0546 A
0547 N
0548 G
0549 E
0550
0551 O
0552 F
0553
0554 T
0555 H
0556 E
0557
0558 L
0559 O
0560 T
0561 ENDα
0562 RCL      R014
0564 RCL      R018
0566 -
0567 PRINT
0568 PRNTα
0570 =
0571
0572 =
0573
0574 =
0575
0576 =
0577
0578 =
0579
0580 =
0581
0582 =
0583
0584 =
0585
0586 ENDα
0587 SPACE
```

Steps 0542 through 0587 print the message below.

```
RANGE OF THE LOT
    0.000301
= = = = = = = =
```

Register 14 (highest reading) is recalled.

Register 18 (lowest reading) is recalled and subtracted from register 14.

The difference is the range of the lot.

```
0588 PRNTα
0590 A
0591 R
0592 I
0593 T
0594 H
0595 .
0596
0597 M
0598 E
0599 A
0600 N
0601 =
0602 ENDα
0603 RCL     R019
0605 PRINT
0606 PRNTα
0608 S
0609 T
0610 D
0611 .
0612
0613 D
0614 E
0615 V
0616 .
0617 =
0618 ENDα
0619 RCL     R020
0621 PRINT
0622 RCL     R026
0624 SQRT
0625 STO     A
0626 RCL     R020
0628 RCL     A
0629 ÷
0630 STO     A
0631 PRNTα
0633 S
0634 T
0635 D
0636 .
0637
0638 E
0639 R
0640 R
0641 O
0642 R
0643 =
0644 ENDα
0645 RCL     A
0646 PRINT
0647 PRNTα
0649 =
0650
0651 =
0652
0653 =
0654
0655 =
0656
0657 =
0658
0659 =
0660
0661 =
0662
0663 =
0664
0665 ENDα
```

Steps 0588 through 0665 print the message below.

```
ARITH. MEAN=
    0.313239
STD. DEV.=
    0.000094
STD. ERROR=
    0.000021
= = = = = = = =
```

Register 19 (mean) is recalled and printed.

Register 20 (Std. deviation) is recalled and printed.

Register 26 (No. of data entries) is recalled and its square root is taken.

This number is stored in register A.

Register 20 is recalled. (Std. deviation)

Register A is recalled and divided into register 20.

The result is stored in register A.

Register A (std. error) is recalled and printed.

Steps 0666 through 0762 print the message below.

```
0666 SPACE
0667 PRNTα
0669 M
0670 A
0671 X
0672 .
0673
0674 O
0675 V
0676 A
0677 L
0678 .
0679
0680 0
0681 -
0682 9
0683 0
0684 =
0685 ENDα
0686 RCL      R021
0688 PRINT
0689 FIX      0
0691 RCL      R022
0693 PRNTα
0695
0696
0697 A
0698 T
0699
0700 L
0701 E
0702 V
0703 E
0704 L
0705
0706 PRINT
0707 ENDα
```

```
0708 PRNTα
0710
0711
0712
0713
0714
0715
0716 *
0717 *
0718 *
0719 ENDα
0720 PRNTα
0722 M
0723 A
0724 X
0725 .
0726 O
0727 V
0728 A
0729 L
0730
0731 4
0732 5
0733 -
0734 1
0735 3
0736 5
0737 =
0738 ENDα
0739 FIX      6
0741 RCL      R027
0743 PRINT
0744 FIX      0
0746 RCL      R028
0748 PRNTα
0750
0751
0752 A
0753 T
0754
0755 L
0756 E
0757 V
0758 E
0759 L
0760
0761 PRINT
0762 ENDα
```

```
 MAX. OVAL. 0-90=
     0.000126
   AT LEVEL      3
        ***
 MAX.OVAL 45-135=
     0.000121
   AT LEVEL      4
 * * * * * * * *
```

Register 21 (max. ovality 0-90 deg.0 is recalled and printed.

Register 22 (level) is recalled and printed.

Register 27 (max. ovality) (45-135 degrees) is recalled and printed.

Register 28 (level) is recalled and printed.

Label D is programmed in next.

-Label D-

```
0763 LBL
---- D
0765 RCL     R004
0767 1
0768 -
0769 STO     R004
0771 CLRA→J
0772 PRNTα
0774 *
0775
0776 *
0777
0778 *
0779
0780 *
0781
0782 *
0783
0784 *
0785
0786 *
0787
0788 *
0789
0790 ENDα
0791 SPACE
0792 SPACE
0793 RCL     R004
0795 5
0796 0
0797 +⇟-
0798 IF X=Y
0799 GOTO    L99
0801 RCL     R004
0803 IDENT
0804 ROLL↓
0805 ROLL↓
0806 ROLL↓
0807 5
0808 IF X=Y
0809 GOTO    L99
0811 GOTO    B
```

Register 4i is recalled.

1 is subtracted from it and it is restored in register 4.

Registers A through J are cleared.

8 asterisks are printed across the tape to signify the end of the summary by hole for the lot.

Register 4 is recalled and compared to -50.

If the numbers equal, label 99 is addressed.

If the numbers don't equal, register 4 is recalled, and the file with that number is identified.

Its file type is compared to the number 5.

If the numbers equal, label 99 is addressed.

If the numbers don't equal, label B is addressed.

-Label 99-

```
0813 LBL
---- 99
0815 RCL     R004
0817 +≑-
0818 2
0819 1
0820 -
0821 PRNTα
0823 PRINT
0824
0825 H
0826 O
0827 L
0828 E
0829
0830 L
0831 O
0832 T
0833
0834
0835
0836 ENDα
0837 PRNTα
0839 =
0840 =
0841 =
0842 =
0843 =
0844 =
0845 =
0846 =
0847 =
0848 =
0849 =
0850 =
0851 =
0852 =
0853 =
0854 =
0855 ENDα
0856 PRNTα
0858
0859
0860
0861
0862
0863
0864 *
0865 *
0866 *
0867 ENDα
0868 END
```

Register 4 is recalled.

Its sign is inverted.

21 is subtracted from that number.

The message "Hole Lot" is printed with the above difference.

16 equal signs are printed on the tape.

On the next line 3 asterisks are printed.

File -23

Steps 0000 through 0023 print the message below.

```
FILE    -23
TYPE     0
USED     907
MAX      1000

0000 NOP
0001 NOP
0002 PRNTα
0004 I
0005 N
0006 S
0007 E
0008 R
0009 T
0010
0011 D
0012 A
0013 T
0014 A
0015
0016 T
0017 A
0018 P
0019 E
0020 ENDα
0021 STOP
0022 SPACE
0023 SPACE
```

```
INSERT DATA TAPE
```

When the program stops, data tape is inserted into the computer.

Steps 0024 through 0110 print the message below.

```
. . . . . . . . ..

.   EXECUTIVE    .

.    SUMMARY     .
.-BY DATA LOT-  .

. . . . . . . . ..
```

```
0024 PRNTα
0026 .
0027
0028 .
0029
0030 .
0031
0032 .
0033
0034 .
0035
0036 .
0037
0038 .
0039
0040 .
0041 .
0042 LINE
0043 .
0044
0045
0046 E
0047 X
0048 E
0049 C
0050 U
0051 T
0052 I
0053 V
0054 E
0055
0056
0057
0058 .
0059 LINE
0060 .
0061
0062
0063
0064 S
0065 U
0066 M
0067 M
0068 A
0069 R
0070 Y
0071
0072
0073
0074
0075 .
0076 .
0077 -
0078 B
0079 Y
0080
0081 D
0082 A
0083 T
0084 A
0085
0086 L
0087 O
0088 T
0089 -
0090
0091 .
0092 LINE
0093 .
0094
0095 .
0096
0097 .
0098
0099 .
0100
0101 .
0102
0103 .
0104
0105 .
0106
0107 .
0108 .
0109 ENDα
0110 SPACE
```

-Label A-

```
0111 LBL
---- A
```

50 registers are opened for data storage.

```
0113 5
0114 0
0115 #REGS
```

Registers A through J are cleared.

```
0116 CLRA→J
```

Register X in the stack is cleared.

```
0117 CLX
0118 FIX     0
```

File -21 (data tape) is loaded into the computer.

```
0120 5
0121 0
0122 #REGS
0123 5
0124 0
0125 #REGS
0126 0
0127 0
0128 ENTER↑
0129 2
0130 1
0131 +⇌-
0132 LOAD
```

Register 17 (data source) is recalled and printed.

```
0133 RCL     R017
0135 PRNTα
0137 D
0138 A
0139 T
0140 A
0141
0142 S
0143 O
0144 U
0145 R
0146 C
0147 E
0148
0149 PRINT
0150 ENDα
```

Register 15 (data lot) is recalled and printed.

```
0151 RCL     R015
0153 PRNTα
0155 D
0156 A
0157 T
0158 A
0159
0160 L
0161 O
0162 T
0163
0164 PRINT
0165 ENDα
0166 SPACE
0167 CLEAR
0168 PRNTα
0170 *
0171
0172 *
0173
0174 *
0175
0176 *
0177
0178 *
0179
0180 *
0181
0182 *
0183
0184 *
0185
0186 ENDα
```

Label C is addressed.

```
0187 GOTO    C
```

-Label B-

```
0189 LBL
---- B
0191 CLX
0192 5
0193 0
0194 #REGS
0195 FIX     0
0197 5
0198 0
0199 #REGS
0200 0
0201 0
0202 ENTER↑
0203 RCL     R004
0205 LOAD
```

Register X in the stack is cleared.

Register 04 is recalled and the file with that number is loaded into the computer.

-Label C-

```
0206 LBL
---- C
0208 RCL     R013
0210 RCL     R033
0212 +
0213 STO     R033
0215 RCL     R034
0217 RCL     R014
0219 IF X<Y
0220 GOTO    D
0222 STO     R034
0224 RCL     R025
0226 STO     R031
```

Register 13 (no. of entries) is recalled.

Register 33 is recalled and is added to register 13.

The total is stored in Register 33.

Register 34 is recalled.

Register 14 is recalled and is compared to register 34.

If Register 14 is less than register 34, label D is addressed.

If register 14 is equal to or greater than register 34, it is stored in register 34.

Register 25 (hole number) is recalled.

It is stored in register 31.

-Label D-

```
0228 LBL
---- D
0230 RCL    R038
0232 IF 0
0233 GOTO   L10
0235 RCL    R018
0237 IF X≥Y
0238 GOTO   E
0240 STO    R038
0242 RCL    R025
0244 STO    R032
0246 GOTO   E
```

Register 38 is recalled.

If it is empty (0), label 10 is addressed.

If it caontains data, register 18 is recalled and they are compared.

If register 18 is equal to or greater than register 38, label E is addressed.

If register 18 is less than register 38, it is stored in register 38.

Register 25 (hole number) is recalled.

It is stored in register 32.

Label E is addressed.

-Label 10-

```
0248 LBL
---- 10
0250 RCL    R018
0252 STO    R038
0254 1
0255 STO    R032
```

Register 18 (lowest reading) is recalled.

It is stored in register 38.

1 is stored in register 32.

-Label E-

```
0257 LBL
---- E
0259 RCL    R039
0261 RCL    R021
0263 IF X<Y
0264 GOTO   F
0266 STO    R039
0268 RCL    R025
0270 STO    R040
```

Register 39 is recalled.

Register 21 (max. ovality 0-90 deg.) is recalled and they are compared.

If register 21 is less than register 39, label F is addressed.

If register 21 is equal to or greater than register 39, it is stored in register 39.

Register 25 (hole number) is recalled.

It is stored in register 40.

```
0272 LBL
---- F
0274 RCL      R039
0276 RCL      R027
0278 IF X<Y
0279 GOTO     G
0281 STO      R039
0283 RCL      R025
0285 STO      R040
0287 LBL
---- G
0289 RCL      R023
0291 RCL      R041
0293 +
0294 STO      R041
0296 RCL      R024
0298 RCL      R042
0300 +
0301 STO      R042
0303 RCL      R004
0305 1
0306 -
0307 STO      R004
0309 5
0310 0
0311 +≑-
0312 IF X=Y
0313 GOTO     L98
0315 RCL      R004
0317 IDENT
0318 ROLL↓
0319 ROLL↓
0320 ROLL↓
0321 5
0322 IF X=Y
0323 GOTO     L98
0325 GOTO     B
```

-Label F-

Register 39 is recalled.

Register 27 (max. ovality 45-135 deg.) and is compared to register 39.

If register 27 is less than register 39, label G is addressed.

If register 27 is equal to or greater than register 39, it is stored in register 39.

Register 25 (hole number) is recalled.

It is stored in register 40.

-Label G-

Register 23 is recalled.

Register 41 is recalled and is added to register 23.

The total is stored in register 41.

Register 24 is recalled.

Register 42 is recalled and is added to register 24.

The total is stored in register 42.

Register 4 is recalled.

1 is subtracted from it and it is restored in register 4.

This number is compared to a -50.

If register 4 equals -50, label 98 is addressed.

If register 4 does not equal -50, register 4 is recalled and the file with that number is identified. Its file type is compared to the number 5. (Empty file).

If they equal, label 98 is addressed.

If they don't equal, label B is addressed.

-Label 98-

```
0327 LBL
---- 98
0329 FIX     0
0331 RCL     R033
0333 PRNTα
0335 PRINT
0336
0337 D
0338 A
0339 T
0340 A
0341
0342 E
0343 N
0344 T
0345 R
0346 I
0347 E
0348 S
0349 ENDα
0350 PRNTα
0352 =
0353
0354 =
0355
0356 =
0357
0358 =
0359
0360 =
0361
0362 =
0363
0364 =
0365
0366 =
0367
0368 ENDα
0369 SPACE
```

Register 33 is recalled.

The message "_______data entries" is printed with the number in register 33.

```
* * * * * * * *
580 DATA ENTRIES
= = = = = = = =
```

```
0370 PRNTα
0372 H
0373 O
0374 L
0375 E
0376
0377 S
0378 I
0379 Z
0380 E
0381 *
0382 ENDα
0383 FIX      6
0385 RCL      R012
0387 PRNTα
0389
0390
0391 U
0392 P
0393 P
0394 E
0395 R
0396
0397 L
0398 I
0399 M
0400 I
0401 T
0402 =
0403 ENDα
0404 PRINT
0405 PRNTα
0407
0408
0409 L
0410 O
0411 W
0412 E
0413 R
0414
0415 L
0416 I
0417 M
0418 I
0419 T
0420 =
0421 ENDα
0422 RCL      R011
0424 PRINT
```

Steps 0375 **through** 0429 **print the message below.**

```
HOLE SIZE*
  UPPER LIMIT=
    0.315000
  LOWER LIMIT=
    0.312000
```

Register 12 (upper limit tolerance) is recalled and printed.

Register 11 (lower limit tolerance) is recalled and printed.

Steps 0425 through 0498 print the message below.

```
= = = = = = = =

HIGHEST READING=
     0.314753
  AT HOLE          8
      ***
```

```
0425 PRNTα
0427 =
0428
0429 =
0430
0431 =
0432
0433 =
0434
0435 =
0436
0437 =
0438
0439 =
0440
0441 =
0442
0443 ENDα
0444 SPACE
0445 PRNTα
0447 H
0448 I
0449 G
0450 H
0451 E
0452 S
0453 T
0454
0455 R
0456 E
0457 A
0458 D
0459 I
0460 N
0461 G
0462 =
0463 ENDα
0464 FIX      6
0466 RCL      R034
0468 PRINT
```

Register 34 (highest reading) is recalled and printed.

```
0469 FIX      0
0471 RCL      R031
0473 PRNTα
0475
0476
0477 A
0478 T
0479
0480 H
0481 O
0482 L
0483 E
0484
0485 PRINT
0486 ENDα
0487 PRNTα
0489
0490
0491
0492
0493
0494
0495 *
0496 *
0497 *
0498 ENDα
```

Register 31 (hole number) is recalled and printed.

Steps 0499 through 0551 print the message below.

```
LOWEST READING=
      0.312948
   AT HOLE        3
         ***
```

```
0499 PRNTα
0501 L
0502 O
0503 W
0504 E
0505 S
0506 T
0507
0508 R
0509 E
0510 A
0511 D
0512 I
0513 N
0514 G
0515 =
0516 ENDα
0517 FIX      6
0519 RCL      R038
0521 PRINT
```

Register 38 (lowest reading) is recalled and printed.

```
0522 FIX      0
0524 RCL      R032
0526 PRNTα
```

Register 32 (hole number) is recalled and printed.

```
0528
0529
0530 A
0531 T
0532
0533 H
0534 O
0535 L
0536 E
0537
0538 PRINT
0539 ENDα
0540 PRNTα
0542
0543
0544
0545
0546
0547
0548 *
0549 *
0550 *
0551 ENDα
```

```
0552 FIX      6
0554 PRNTα
0556 M
0557 A
0558 X
0559 .
0560
0561 O
0562 V
0563 E
0564 R
0565 S
0566 I
0567 Z
0568 E
0569 =
0570 ENDα
0571 RCL      R034
0573 RCL      R012
0575 -
0576 IF -
0577 0
0578 PRNTα
0580
0581
0582
0583
0584 +
0585 +
0586 +
0587 +
0588 PRINT
0589 ENDα
0590 PRNTα
0592
0593
0594
0595
0596
0597
0598 *
0599 *
0600 *
0601 ENDα
```

```
0602 PRNTα
0604 M
0605 A
0606 X
0607 .
0608
0609 U
0610 N
0611 D
0612 E
0613 R
0614 S
0615 I
0616 Z
0617 E
0618 =
0619 ENDα
0620 RCL      R011
0622 RCL      R038
0624 -
0625 IF -
0626 0
0627 PRNTα
0629
0630
0631
0632
0633 -
0634 -
0635 -
0636 -
0637 PRINT
0638 ENDα
0639 PRNTα
0641 =
0642
0643 =
0644
0645 =
0646
0647 =
0648
0649 =
0650
0651 =
0652
0653 =
0654
0655 =
0656
0657 ENDα
0658 SPACE
```

Steps 0552 through 0658 print the message below.

```
MAX. OVERSIZE=
    ++++0.000000
       ***
MAX. UNDERSIZE=
    ----0.000000
= = = = = = = =
```

Register 34 is recalled.

Register 12 (upper limit tolerance) is recalled and subtracted from register 34.

If the answer is negative, zeros are printed with 4 plus signs on the tape.

If the answer is positive, it is printed with 4 plus signs on the tape.

Register 11 (lower limit tolerance) is recalled.

Register 38 is recalled and subtracted from register 11.

If the answer is negative, zeros are printed with 4.

If the answer is positive, it is printed with 4 minus signs on the tape.

Steps 0659 through 0705 print the message below.

```
0659 PRNTα
0661 R
0662 A
0663 N
0664 G
0665 E
0666
0667 O
0668 F
0669
0670 T
0671 H
0672 E
0673
0674 L
0675 O
0676 T
0677 ENDα
0678 FIX      6
0680 RCL      R034
0682 RCL      R038
0684 -
0685 PRINT
0686 PRNTα
0688 =
0689
0690 =
0691
0692 =
0693
0694 =
0695
0696 =
0697
0698 =
0699
0700 =
0701
0702 =
0703
0704 ENDα
0705 SPACE
```

```
RANGE OF THE LOT
    0.001805
= = = = = = = =
```

Register 34 is recalled.

Register 38 is recalled and subtracted from register 34.

The difference is the range of the lot.

```
0706 CLRA→J
0707 RCL     R041
0709 STO     C
0710 RCL     R042
0712 STO     D
0713 RCL     R033
0715 STO     E
0716 MN&SD
0717 PRNTα
0719 A
0720 R
0721 I
0722 T
0723 H
0724 .
0725
0726 M
0727 E
0728 A
0729 N
0730 =
0731 ENDα
0732 PRINT
0733 PRNTα
0735 S
0736 T
0737 D
0738 .
0739
0740 D
0741 E
0742 V
0743 .
0744 =
0745 ENDα
0746 X⇌Y
0747 PRINT
0748 STO     R044
0750 RCL     R033
0752 SQRT
0753 STO     R043
0755 RCL     R044
0757 RCL     R043
0759 ÷
0760 PRNTα
0762 S
0763 T
0764 D
0765 .
0766
0767 E
0768 R
0769 R
0770 O
0771 R
0772 =
0773 ENDα
```

Register A through J are cleared.

Register 41 is recalled and stored in register C.

Register 42 is recalled and stored in register D.

Register 33 is recalled and stored in register E.

Steps 0706 through 0774 print the message below.

```
ARITH. MEAN=
     0.313416
STD. DEV.=
     0.000263
STD. ERROR=
     0.000011
```

When "MN&SD" is programmed in, the mean is located in the X register.

The standard deviation is located in the Y register as a result of the "MN&SD" function. The X and Y registers are inverted and the standard deviation is printed.

This number is stored in register 44.

Register 33 is recalled and its square root is taken.

This number is stored in register 43.

Register 44 is recalled.

Register 43 is recalled and is divided into register 44.

The result is printed as the standard error.

Steps 0775 **through** 0850 **print the message below.**

```
= = = = = = = =

MAX. OVALITY=
   0.000603
  AT HOLE      8
================
```

Register 39 **(max. ovality) is recalled and printed.**

Register 40 **(hole number0 is recalled and printed.**

```
0775 PRNTα
0777 =
0778
0779 =
0780
0781 =
0782
0783 =
0784
0785 =
0786
0787 =
0788
0789 =
0790
0791 =
0792
0793 ENDα
0794 SPACE
0795 PRNTα
0797 M
0798 A
0799 X
0800 .
0801
0802 O
0803 V
0804 A
0805 L
0806 I
0807 T
0808 Y
0809 =
0810 ENDα
0811 RCL      R039
0813 PRINT
0814 FIX      0
0816 RCL      R040
0818 PRNTα
0820
0821
0822 A
0823 T
0824
0825 H
0826 O
0827 L
0828 E
0829
0830 PRINT
0831 ENDα
0832 PRNTα
0834 =
0835 =
0836 =
0837 =
0838 =
0839 =
0840 =
0841 =
0842 =
0843 =
0844 =
0845 =
0846 =
0847 =
0848 =
0849 =
0850 ENDα
```

```
0851 SPACE
0852 RCL     R004
0854 +÷-
0855 2
0856 1
0857 -
0858 PRNTα
0860 PRINT
0861
0862 H
0863 O
0864 L
0865 E
0866
0867 L
0868 O
0869 T
0870
0871
0872
0873 ENDα
0874 SPACE
0875 PRNTα
0877 =
0878 =
0879 =
0880 =
0881 =
0882 =
0883 =
0884 =
0885 =
0886 =
0887 =
0888 =
0889 =
0890 =
0891 =
0892 =
0893 ENDα
0894 PRNTα
0896
0897
0898
0899
0900
0901
0902 *
0903 *
0904 *
0905 ENDα
0906 END
```

Steps 0851 through 0906 print the message below.

```
   29 HOLE LOT

================
      ***
```

Register 4 is recalled.

-21 is subtracted from register 4.

The difference is the number of holes in the lot.

APPENDIX D

DATA ANALYSIS SUMMARIES BY RANK

DRILL METHOD SE

RANKING NUMBER 1 *

HOLE SIZE: 0.246"/0.250"

I. OVERVIEW:

A. This set of survey holes features Spacematic drilling, cold-work split-sleeve/mandrel expansion and final hand reaming of holes in a Center Wing Lower Surface, along the Rear Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the Rear Spar cap. The approximate thickness in the area surveyed was 0.70" at W.S. 0.00.

The subject hole is sized by Engineering at 0.235"/0.238" as the starting hole for cold-working per specification and the final ream size at 0.246"/0.250" per Specification.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious end product quality advantage.

II. SUMMARY:

A. Reference "Executive Histogram by Data Lot". The data population for this set is densely situated about the 0.2471"/0.2473" zone of the overall 0.246"/0.250" tolerance band.

* DRILL METHOD CODING: SE-1 = Spacematic with Expansion Spacematic drilling, cold-work split sleeve/mandrel expansion, final hand reaming.

The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference "Executive Summary by Data Lot". This set discloses a measurement distribution whose arithmetical average is 0.247170" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1044 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference "Executive Summary by Data Lot" discloses an arithmetical average of 0.247170" which is excellent for the set and is reflected in the quality of the holes.

Extremely slight reamer center-seeking and irregular chip load spurs in several of the holes are the only geometric features departing from otherwise excellent cylindrical holes.

All of the specimens conform to the tolerance criterion established by Engineering.

This set is an extraordinary good series of holes. Twenty-five (25) holes, identified Holes #2 thru 15, 17 thru 21, 23 thru 25 and 27 thru #29 are nearly perfect specimens with less than 0.0003" variation exiting in the thirty-six (36) measurements recorded for each individual hole.

Reference Individual Computer Printouts. The range of measurements for the above holes were recorded as follows:

Center Wing S/N 215

Hole #	Range	Hole #	Range
2	0.000216"	7	0.000112"
3	0.000181"	8	0.000233"
4	0.00181"	9	0.000172"
5	0.000302"	10	0.000207"
6	0.000250"	11	0.000310"

Hole #	Range	Hole #	Range
12	0.000259"	20	0.000155"
13	0.000233"	21	0.000164"
14	0.000302"	23	0.000095"
15	0.000310"	24	0.000207"
17	0.000198"	25	0.000200"
18	0.000302"	27	0.000293"
19	0.000284"	28	0.000198"
		29	0.000233"

In the above series of holes, Holes #5, 8 and #29 exhibit extremely slight and shallow bellmouth at the start plane of reaming. This feature is attributed to reamer center-seeking at the start of its duty cycle.

The remainder of the above listed holes feature exceedingly slight "spurs" at various measurement plane levels and axes within the holes. The "spurs" are a result of chip load irregularity.

Both of the aforenoted features are so very minute, neither is assessed a detriment to hole quality and is not perceptible via visual inspection of the specimens at 3X magnification.

1. The four (4) holes remaining in this set exhibit the following range and causes for very minute departures from true cylindricity.

Reference Individual Hole Computer Printouts.

Hole #1; measurement range 0.000328". Irregular breakout spur by the reamer at its exit plane of the hole and only at its 90^{o} axis.

Hole #16; measurement range 0.000526". Irregular breakout spur by the reamer at its exit plane of the hole and only at its 90^{o} axis.

Hole #22; measurement range 0.000655". Slight operator induced side load during the reaming duty cycle, predominantly along the adjacent 0^{o} and 135^{o} axes of measurement. The breakout spur at the 0^{o} axis, last plane of measurements is the largest measurement in this hole and recorded at 0.247759", well within the overall 0.245".0.250" Engineering tolerance.

Hole #26; measurement range 0.000379". Extremely minute irregular chip load spurs inside the hole.

None of the aforenoted characteristics are significant enough to be classified a detriment to overall quality of the holes. This set is an exceptionally good series of holes.

B. Ovality:

Maximum recorded ovality within the set occurred at Hole #22 and discloses a value of 0.000422" on the 0^{o} - 90^{o} axes at plane #9. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the side load and irregular reamer breakout in this hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements,

(predominantly less than 0.0002"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2^{o}.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Several holes of this set exhibit a very slight bellmouth feature at the start vicinity of reaming. Refer to narrative at paragraph III.A.1 and III.A.2 for details.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

RANKING NUMBER 2 DELETED

DRILL METHOD Q-3

RANKING NUMBER 3 *

HOLE SIZE: 0.6270"/0.6280"

I. OVERVIEW:

A. This set of production holes features drill, reaming and cold work roller burnishing of the Structural Fin. The structure is a very heavy machined fin skin whose thickness is tapered on both the inner and outer faying surfaces to match interfacing structure. Owing to the tapers with regard to the "thru-hole" air probe, an engagement length in the holes of approximately 0.70" was measured to avoid bleed out at the tapered faces. The subject hole is sized by Engineering at 0.6270"/0.6280".

II. SUMMARY:

A. This set of holes, roller burnished to achieve final Engineering size, is the most perfect geometrically configured and finish textured series of holes from all lots surveyed at this facility.

Twenty-nine (29) holes were available from a series of Fin Assemblies to accrue the aforenoted sampling set size. The method of production featured Quackenbush preliminary hole drilling and reaming. These operations were followed by cold worked roller-burnishing to achieve the final hole size per Engineering criterion.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.627484" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point of the Engineering tolerance range. All of the holes for this set meet the Engineering Criteria.

* DRILL METHOD CODING: Q-3 = Quackenbush - One shot Quackenbush, drill method and accessories; tooling, preliminary pilot hole drilling, core drilling, "Dreamer" combination.

Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed fixturing ensures interchangeability and location reliability. Fixture is extremely heavy to accommodate roller burnishing.

2. Quackenbush drill method and accessory tooling produces very good preliminary holes prior to cold working in the following sequence:

   a. Preliminary pilot hole drilling to 0.500" diameter.
   b. Core drilling to 35/64" diameter.
   c. Dreamer combination drill/ream to 0.6265"/0.6270".

3. Cold work roller burnishing to final Engineering size at 0.6270"/0.6280".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS:</u>

A. Hole Size: 1064 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.627484", is an ideal characteristic in regard to the Engineering criterion of 0.6270"/0.6280". This is an excellent series of holes on size, geometric features and hole finish texture.

1. Reference to Individual Computer Printout discloses an <u>excellent overall measurement range</u> from the highest to lowest reading within the thirty-six (36) to forty (40) measurements <u>per hole</u>. The range of measuresments are as follows:

Hole #	Range	Hole #	Range
1	0.000362"	16	0.000319"
2	0.000414"	17	0.000517"
3	0.000448"	18	0.000391"
4	0.000491"	19	0.000267"
5	0.000414"	20	0.000319"
6	0.000319"	21	0.000353"
7	0.000466"	22	0.000293"
8	0.000405"	23	0.000440"
9	0.000475"	24	0.000500"
10	0.000267"	25	0.000422"
11	0.000440"	26	0.000353"
12	0.000276"	27	0.000388"
13	0.000388"	28	0.000595"
14	0.000672"	29	0.000440"
15	0.000388"		

Focus onto the above measurement ranges was for the purpose of drawing attention to the fact that this series of holes are nearly perfect. Several holes exhibit an extremely slight bulge enlargement generally along one (1) axis of measurements interpreted as a failure to "clean-out" due to minute concentricity differences between the Dreamer (0.6265"/0.6270") operation and final roller burnishing (0.6270"/ 0.6280").

2. Reference Individual Hole Computer Printouts and item III.A.1. above. Nine (9) holes exhibit a slight bulge identified via Computer Profile Printout and Measurement Data. The specific holes and bulge orientations are identified as follows:

Hold #	Axis Affected	Magnitude max. & plane level
2	135°	.0002" at level 6 and 7
3	135°	.0002" at level 5
4	45°	.0002" at level 5, 6 and 7
5	135°	.0003" at level 5, 6 and 7
7	0°	.0002" at level 4,5,6 and 7
9	135°	.0002" at level 6
14	45°	.0003" at level 4 and 5
23	0°	.0003" at level 5 and 6
24	0°	.0003" at level 5

Note: In all cases, the bulge configuration was not evident as a physical mar or defect of abrupt shape and/or geometry. Very subtle finish texture identifiable by variation of light reflection identified the locations and orientation. Orientations were confirmed via hole indexing from which measurements were taken by "thru-hole" air probe. All holes, including the bulge measurements were well within the Engineering tolerance criterion. The bulges were not considered a detriment to hole quality by this analysis effort.

3. Reference to Individual Hole Histograms reveal an excellent dispersion of data elements populated about the mid-range of the hole tolerance zone. The Normal Gausian Distribution representative of this data is suggestive of tools, personnel and processes functioning in complete harmony. This series of holes, considering all geometric features and hole finish texture are excellent.

Reference Executive Summary Histogram. The data population is excellent and crowds the mid-range of the tolerance zone. Again, as per the Individual Hole Histograms, a Normal Gausian Distribution

is evident signifying controlled hardware processing and notable craftsmanship on the finished product.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #14 and discloses a value of 0.000672" at plane level #9 on the 45° -135° axes. Enlargement at the exit plane of measurements most probably is the result of irregular breakout of the Dreamer that failed to "clean-up" on roller burnishing. The ovality magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout disclosed all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures correct angularity of the holes with regard to faying surfaces of interfacing structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The longitudinal axis of the hole was verified to be 5° closed with regard to the outboard machined face of the structure, measured normal (90°) to the Fin Waterline 2.000 reference and along Fin Stations 18.996 and 23.997.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: None existent as evidenced by profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This structure, drilled, reamed and roller burnished through one (1) solid flange was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish significantly superior to "63 AA" and approximating "32AA". Surface was smooth and shiny. Surface finish differences helped confirm the presence of the minute bulges described per narrative at items III.A.1. and III.A.2.

DRILL METHOD SE

RANKING NUMBER 4 *

HOLE SIZE: 0.246"/0.250"

I. OVERVIEW:

A. This set of survey holes features Spacematic drilling, cold-work split-sleeve/mandrel expansion and final hand reaming of holes in a Center Wing Surface, along the Center Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the center spar cap. The approximate thickness in the area surveyed was 0.80" at W.S. 0.00 and tapered to 0.60" at W.S. 66.00.
The subject hole is sized by Engineering at 0.235"/0.238" as the starting hole for cold-working per specification and the final ream size at 0.246"/0,250" per specification.

* DRILL METHOD CODING: SE = Spacematic with Expansion
Spacematic drilling, cold work split sleeve/mandrel expansion, final hand reaming.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious end product quality advantage. Location for the holes of this set were selected purposely for their disclear of any interference on the assembly fixture to compare final hole quality to that of these holes which were in inaccessible areas.

II. SUMMARY:

A. Reference "Executive Histogram by Data Lot." The data population for this set is densely situated about the 0.2470"/0.2473" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.247227" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1044 data measurements were accrued from the twenty-nine (29) holes comprising this set Reference Executive Summary by Data Lot discloses an arithmetical average of 0.247227" which is excellent for the set and is reflected in the quality of the holes.

All of the specimens conform to the tolerance criterion established by Engineering and there are no significant geometric features degrading the overall integrity of these holes.

1. Seventeen (17) holes, identified Hol. #3, 5, 6, 7, 9, 12, 13, 14, 15, 16, 17, 18, 20, 23, 26, 28 and #29 are nearly perfect specimens. Less than 0.0003" variation exists in the series of thirty-six (36) measurements recorded for <u>each</u> individual hole.

   Reference Individual Hole Computer Printouts. The range of measurements for the above holes were recorded as follows:

   Center Wing S/N 215

Hole #	Range	Hole #	Range
3	0.000233"	16	0.000250"
5	0.000250"	17	0.000207"
6	0.000267"	18	0.000190"
7	0.000138"	20	0.000241"
9	0.000241"	23	0.000284"
12	0.000284"	26	0.000267"
13	0.000181"	28	0.000198"
14	0.000293"	29	0.000224"
15	0.000198"		

   The above listed holes reveal exceedingly slight "spurs" at various measurement plane levels and axes within the holes which most probably is a result of chip load irregularity. It is not considered a detriment to hole quality and is not perceptible via visual inspection of the specimen at 3X magnification.

2. Extending the variation limit criterion to less than 0.0005" in magnitude introduces ten (10) additional holes from this set.
These holes, identified Hole #1, 4, 8, 10, 11, 19, 22, 24, 25 and #27 are virtually the same quality integrity as Item III.A.1 holes.

Reference Individual Hole Computer Printouts. The range of measurements for the above noted holes were recorded as follows:

Center Wing S/N 215

Hole #	Range	Hole #	Range
1	0.000319"	19	0.000253"
4	0.000319"	22	0.000491"
8	0.000336"	24	0.000336"
10	0.000314"	25	0.000310"
11	0.000422"	27	0.000371"

Reference to Individual Computer Printout Data for the above series of holes discloses an identifiable, extremely minute, bellmouth feature at Hole #8, 10 and #22 and very slight "spurs" at various measurement planes and axes in the remainder of the holes.

The bellmouth characteristic is a consequence of very slight center-seeking of the reamer at the start of its duty cycle. The data "spurs" are a product of irregular chip load. Both are exceptionally minute. Neither of these characteristics are significant enough to be considered a degradation to hole quality.

3. Hole #21 is the largest hole of the set and recorded its greatest measurement at 0.248422" at the exit plane of the hole. Reference Individual Computer Printout reveals the feature to be a consequence of irregular breakout at the completion of reaming. It is extremely minute and not a detriment to overall hole quality.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #21 and discloses a value of 0.001138" on the 0° - 90° axes at plane #9. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of minute irregular reamer breakout at completion of its duty cycle.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (generally less than 0.0001"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by holes referenced in III.A.1 thru III.A.2 narrative.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD SE

RANKING NUMBER 5 *

HOLE SIZE: 0.246"/0.250"

I. <u>OVERVIEW</u>:

A. This set of survey holes features Spacematic drilling, cold-work split-sleeve/mandrel expansion and final hand reaming of holes in the Center Wing Lower Surface, along the Front Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the front spar cap. The approximate thickness in the area surveyed was 0.95" at W.S. 0.00 and tapered to 0.88" at W.S. 44.50. The subject hole is sized by Engineering at 0.235"/0.238" as the starting hole for cold-working per specification and the final ream size at 0.246".0.250" per Specification.

* DRILL METHOD CODING: SE = Spacematic with Expansion
Spacematic drilling, cold work split sleeve/mandrel expansion, final hand reaming.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious end product quality advantage.

II. SUMMARY:

A. Reference Executive Histogram by Data Lot. The data population for this set is densely situated about the 0.2471"/0.2475" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.247314" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Sizes: 1044 data measurements were accrued from the twenty-nine (29) holes comprising this set.Reference Executive Summary by Data Lot discloses an airthmetical average of 0.247314" which is excellent for the set and is reflected in the quality of the holes.

All of the specimens conform to the tolerance criterion established by Engineering. Several holes in this set exhibit an extremely slight lobing and/or bulging features which are the only departures from otherwise perfectly cylindrical holes.

1. Eight (8) holes, identified Hole #1, 2, 8, 19, 20, 21, 22 and #26 are nearly perfect specimens. Less than 0.0003" variations exists in the series of thirty-six (36) measurements recorded for each individual hole.

   Reference Individual Hole Computer Printouts. The range of measurements for the above holes were recorded as follows:

   Center Wing ~~S/N 215~~

Hole #	Range	Hole #	Range
1	0.000233"	20	0.000190"
2	0.000172"	21	0.000233"
8	0.000250"	23	0.000241"
19	0.000172"	26	0.000147"

   The above listed holes reveal exceedingly slight "spurs" at various measurement plane levels and axes within the holes which most probably is a result of chip load irregularity. It is not considered a detriment to hole quality and is not perceptible via visual inspection of the specimens at 3X magnification.

2. Extending the variation limit criterion to less than 0.0005" in magnitude introduces sixteen (16) additional holes. These holes, identified Hole #5, 6, 7, 9, 11, 12, 13, 14, 15, 16, 18, 23, 25, 27, 28 and #29 are virtually the same quality integrity as item III.A.1 holes.

   Reference Individual Hole Computer Printouts. The range of measurements for the above noted holes were recorded as follows:

Center Wing ~~S/N 215~~

Hole #	Range	Hole #	Range
5	0.000319"	15	0.000498"
6	0.000362"	16	0.000457"
7	0.000500"	18	0.000362"
9	0.000310"	23	0.000345"
11	0.000405"	25	0.000320"
12	0.000353"	27	0.000371"
13	0.000336"	28	0.000371"
14	0.000328"	29	0.000362"

Reference Individual Hole Computer Printouts. Holes identified #5, 6, 9, 11, 15, 16 and #18 all exhibit slight bulges at various plane levels of measurement per their Axes Profile Data Printout. The most probable cause of this phenomenon is suggested as chip build up and/or coolant starvation during final reaming.

Holes #14, 23 and #28 feature insignificant enlargement at the entrance to the holes. Reamer center-seeking is assessed the most probable cause for the feature.

The remainder of holes in item III.A.2 display slight lobes of enlargement at magnitudes of 0.0001" to 0.0003", most probably the result of irregular chip load (clearing) during the final reaming cycle.

The features discussed for item III.A.2 holes above are extremely minute and are not considered degrading to the overall quality of these holes.

3. Hole #10 is the largest hole of the set and recorded its greatest measurement at 0.247879" at the exit plane of the hole. Hole Computer Printout suggests the feature to be a result of side-loading by the operator during the reaming duty cycle. The characteristic is predominant along the lower portion of the 0° and 45° Axes. Although the side-load feature exists, Hole #10 is well within the criterion established by Engineering.

4. All of the features noted in items III.A.1 through III.A.3 are considerably slight as a departure from a truly cylindrical hole.

The use of assist tooling for stablizing the powerhead, reamer and operator is apparent in the data and the overall quality of this series of holes is very good. The fact that <u>all</u> of the holes are within tolerance attest to the craftsmanship, skill and knowledgeable use of tooling.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #10 and discloses a value of 0.000698" on the 45° - 135° axes at plane #9. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the side-load feature in this hole.

Ovality was not a cause for concern on this set Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (generally less than 0.0003"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Non-existent as evidenced by profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

4. All of the features noted in items III.A.1 through III.A.3 are considerably slight as a departure from a truly cylindrical hole.

The use of assist tooling for stablizing the powerhead, reamer and operator is apparent in the data and the overall quality of this series of holes is very good. The fact that all of the holes are within tolerance attest to the craftsmanship, skill and knowledgeable use of tooling.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #10 and discloses a value of 0.000698" on the 45° - 135° axes at plane #9. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the side-load feature in this hole.

Ovality was not a cause for concern on this set Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (generally less than 0.0003"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Non-existent as evidenced by profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD SE

RANKING NUMBER 6 *

HOLE SIZE: 0.246"/0/250"

I. <u>OVERVIEW:</u>

A. This set of survey holes features Spacematic drilling, cold-work split-sleeve/mandrel expansion and final hand reaming of holes in a Center Wing Lower Surface, at the Center Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the center spar cap. The approximate thickness in the area surveyed was 0.60" at W.S. 44.50 to W.S. 66.00.

The subject hole is sized by Engineering at 0.235"/0.238" as the starting hole for cold-working per specification and the final ream size at 0.246"/0.250" per Specification.

* DRILL METHOD CODING: SE = Spacematic with Expansion
Spacematic drilling, cold-work split/sleeve mandrel expansion, final hand reaming.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious end product quality advantage. Location for the holes of this setwere selected purposely from areas clear of any interference on the assembly fixture to compare final hole quality to that of holes which were essentially located in the same wing area.

II. <u>SUMMARY</u>:

A. Reference Executive Histogram by Data Lot. The data population for this set is densely situated about the 0.2472"/0.2474" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this setmeet the established Engineering criterion. Reference Executive Summary by Data Lot.This set discloses a measurement distribution whose arithmetical average is 0.247362" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 928 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.247362" which is excellent for the set and is reflected in the quality of the holes.

All of the specimens conform to the tolerance criterion established by Engineering and there are no significant geometric features degrading the overall integrity of these holes.

1. Eighteen (18) holes, identified Hole #1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 17, 18, 20, 23, 24, 27 and #29 are nearly perfect specimens. Less than 0.0003" variation exists in the series of thirty-two (32) measurements recorded for <u>each</u> individual hole.

   Reference Individual Hole Computer Printouts. The range of measurements for the above holes were recorded as follows:

   Center Wing S/N 216

Hole #	Range	Hole #	Range
1	0.000250"	14	0.000233"
2	0.000302"	15	0.000302"
3	0.000198"	17	0.000293"
4	0.000121"	18	0.000302"
6	0.000181"	20	0.000302"
7	0.000155"	23	0.000216"
8	0.000284"	24	0.000302"
9	0.000276"	27	0.000250"
10	0.000207"	29	0.000302"

   The above listed holes reveal exceedingly slight "spurs" at various measurement plane levels and axes within the holes which most probably is a result of chip load irregularity. It is not considered a detriment to hole quality and is not perceptible via visual inspection of the specimen at 3X magnification.

2. Extending the variation limit criterion to less than 0.0005" in magnitude introduces the remaining eleven (11) holes from this set. These holes, identified Hole #5, 11, 12, 13, 16, 19, 21, 22, 25, 26 and #28 are virtually the same quality integrity as Item III.A.1 holes.

Reference Individual Hole Computer Printouts. The range of measurements for the above noted holes were recorded as follows:

Center Wing S/N 216

Hole #	Range	Hole #	Range
5	0.000362"	19	0.000431"
11	0.000336"	21	0.000379"
12	0.000319"	22	0.000509"
13	0.000357"	25	0.000379"
16	0.000466"	26	0.000483"
		28	0.000483"

Reference to Individual Computer Printout Data for the above series of holes discloses an identifiable, extremely minute, bellmouth feature.

The slight bellmouth feature for the holes of item III.A.2 is a consequence of very slight center-seeking of the reamer at the start of its duty cycle. The data "spurs", a feature in the holes of item III.A.1 are a product of irregular chip load. Both are exceptionally minute. Neither of these characteristics are significant enough to be considered a degradation to hole quality.

3. Hole #5 is the largest hole of the set and recorded its greatest measurement at 0.247810" at the start plane of the hole. Reference Individual Computer Printout reveals the feature to be a consequence of reamer center-seeking at the start of its duty cycle. It is extremely minute, shallow and not a detriment to overall hole quality.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #22 and discloses a value of 0.000388" on the 45^{o} - 135^{o} axes at plane #1. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of minute, irregular reamer start on entrance to the hole. The feature is insignificant and not assessed a detriment to the quality of the hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (generally less than 0.0001"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by holes referenced in III.A.1 thru III.A.2 narrative.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 7*

HOLE SIZE 0.4375"/0.4405"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Longeron, outboard of the Forward Engine Mount but in the same structural interface station plane. The structure is aluminum approximately .700" thick at the surface to be drilled and reamed. The hole being inspected is sized at 0.4375"/0.4405" by Engineering.

II. SUMMARY:

A. Only seventeen holes were inspected in this set owing to the fact that additional structures to complete a twenty-nine (29) hole sample set were unavailable for inspection. Subsequent assembly fixtures were using the subject holes as locator "hard points" for assembly continuation. The structures representative of the seventeen holes for this set was available on the production line on a non-interference basis. Inspection was performed by "thru-hole air probe".

The computer data Statistical Printout for this series of holes provides a classic composite traceable to the following for the production of good holes:

1. Good fixture design for interface control/interchangeability reliability and Quackenbush drill adaptation.

2. Quackenbush drill/reaming method and accessories producing good holes.

3. Planning is excellent for inspection traceability on holes.

4. "Drill Kit & Pre-Set Orders" (DKPO) identified in the planning provides the technician performing the drill/reaming task with a freshly inspected, cleaned, controlled set of new or refurbished tools (drill motor, drills, reamers, bushings, etc.) to accomplish a specific task on a one time use only basis.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power, Reamer, Mechanical Quackenbush drill adaptation. Quackenbush drill/reaming.

III. CHARACTERISTICS:

A. Hole size: All holes were within the allowable Engineering criterion of 0.4375"/0.4405". Holes are individually excellent on size. Measurements were taken at 40 locations within each hole. Hole #9, the best of the set, discloses a range of measurements of only 0.000095" from its max. to min. dimensional readings. Hole #6, exhibiting the greatest variation in measurement range, is only 0.001103". The maximum reading for hole #3 was 0.439353" and its minimum was 0.438250". The profile of this hole discloses a straight taper from start to finish of the drill/ream process. The 0.439353" dimension is at the interface plane of the longeron (forward face) which is the entry face of the drill/ream process. The exit of the hole is 0.438250".

Hole #4 is similar but has only a 0.000560" taper. Refer to the Statistical Printout for complete details of specific measurement and profile.

Since the taper in both hole #4 and hole #6 are only 0.000560" and 0.000095" reamer to bushing "rattle" space is suggested as the cause for taper.

B. Ovality: Maximum recorded ovality within the set was 0.000328" at hole #14. Individual holes within this set (40 measurements per hole) ranged to as low as 0.000095" at hole #6.

The cause for the slight ovality within this set of holes is considered the result of chip load since it generally occurs deep inside the hole and tapers when considering the four (4) plane level readings.

C. Prependicularity: All holes within this set were absolutely normal to the longitudinal axis of the hole with regard to the machined face (interface surface), the forward face of the longeron structure. Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD SE

RANKING NUMBER 8 *

HOLE SIZE: 0.246"/0.250"

I. OVERVIEW:

A. This set of survey holes features Spacematic drilling, cold-work split- sleeve/mandrel expansion and final hand reaming of holes in a Center Wing Lower Surface, along the Front Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the front spar cap. The approximate thickness in the area surveyed was 0.95" and tapered to 0.88".
The subject hole is sized by Engineering at 0.235"/0.238" as the starting holes for cold-working per specification and the final ream size at 0.246"/0.250" per Specification.

* DRILL METHOD CODING: SE = Spacematic with Expansion Spacematic drilling, cold-work split sleeve/mandrel expansion, final hand reaming.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious end product quality advantage.

II. SUMMARY:

A. Reference Executive Histogram by Data Lot. The data population for this set is densely situated about the 0.2471"/0.2474" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.247269" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1044 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.247269" which is excellent for the set and is reflected in the quality of the holes.

An extremely slight bellmouth characteristic and chip load spurs in several of the holes are the only geometric features departing from otherwise excellent cylindrical holes.

All of the specimens conform to the tolerance criterion established by Engineering.

1. Thirteen (13) holes, identified Hole #2, 6, 7, 8, 11, 18, 20, 22, 23, 24, 25, 28 and #29 are nearly perfect specimens. Less than 0.0003" variation exists in the series of thirty-six (36) measurements recorded for each individual hole.

   Reference Individual Hole Computer Printouts. The range of measurements for the above holes were recorded as follows:

   Center Wing ~~S/N 215~~

Hole #	Range	Hole #	Range
2	0.000250"	22	0.000267"
6	0.000284"	23	0.000224"
7	0.000216"	24	0.000155"
8	0.000207"	25	0.000207"
11	0.000190"	28	0.000198"
18	0.000095"	29	0.000207"
20	0.000164"		

   The above listed holes reveal exceedingly slight "spurs" at various measurement plane levels and axes within the holes. The "spurs" are most probably a result of chip load irregularity. It is not considered a detriment to hole quality and is not perceptible via visual inspection of the specimens at 3X magnification.

2. Extending the variation limit criterion to less than 0.0005" in magnitude introduces twelve (12) additional holes

These holes, identified Hole #2, 3, 5, 9, 10, 13, 14, 15, 16, 17, 21 and #27 are virtually the same quality integrity as Item III.A.1 holes.

Reference Individual Hole Computer Printouts. The range of measurements for the above noted holes were recorded as follows:

Center Wing S/N 215

Hole #	Range	Hole #	Range
2	0.000409"	14	0.000414"
3	0.000483"	15	0.000491"
5	0.000345"	16	0.000345"
9	0.000400"	17	0.000457"
10	0.000397"	21	0.000328"
13	0.000395"	27	0.000466"

Holes #3, 9, 10, 14, 17, 21 and #27 above feature a very insignificant bellmouth and/or taper enlargement at the entrance to the holes. Reamer center-seeking at the start of its duty cycle is assessed the most probable cause for bellmouth characteristic. The feature is very shallow and its magnitude generally less than 0.0003". Hole #17 exhibits the greatest depth impingement of the bellmouth condition; However, its magnitude also is only 0.0004".

Holes #5, 13, 15 and #16, the remainder of specimens from the above series, all exhibit the slight "spurs" at various measurement plane levels and axes. Chip load irregularity is deemed the most probable cause of the "spurs".

The overall quality of all of the above holes is very good. The bellmouth and spur characteristics present in the holes are exceedingly slight and are not assessed a degrading feature to hole quality.

3. Hole #12 recorded the largest measurement of the series at a value of 0.248086". This dimension occurred at the first plane of measurements (0.100" down into the hole) and on the 45° axis. The "spike" is a result of center-seeking of the reamer at the start of its duty cycle and it disappears entirely at the next plane of measurements (0.0625" deeper into the hole). Hole #12 exhibits a slight bellmouth feature at the start of the hole and gradually diminishes as depth in the hole is achieved. The condition is only 0.0005" in magnitude at its mouth and is assessed no detriment to overall hole quality.

4. Holes #4, 19 and #26 exhibit very slight bellmouth conditions but are well within the tolerance criterion established per Engineering. Center-seeking of the reamer is assessed the cause for the bellmouth/taper feature.

5. All of the features noted in items III.A.1 through III.A.4 are considerably slight as departures from truly cylindrical holes and are assessed per analysis as very good hole specimens. The use of assist tooling for stabilizing the powerhead, reamer and operator is apparent in the data and the overall quality of this series of holes is very good. The fact that all of the holes are within tolerance attest to the craftsmanship, skill and knowledgeable use of tooling.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #26 and discloses a value of 0.000759" on the 45° - 135° axes at plane #1. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the bellmouth feature in this hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (predominantly less than 0.0002"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Several holes of this set exhibit a very slight bellmouth feature at the start vicinity of reaming. Refer to narrative at paragraph III.A.2 thru III.A.5 for details.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD Q-3

RANKING NUMBER 9*

HOLE SIZE: 0.3770"/0.3790"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Aircraft Structural Fin. The structure is a very heavy machined fin skin whose thickness is 0.360" in the area subject to hole survey. The subject hole is sized by Engineering at 0.3770"/ 0.3790".

II. SUMMARY:

A. Twenty-nine (29) holes were available from structures provided for survey. The method of production featured Quackenbush drilling of preliminary holes, followed by Quackenbush single step drill and reaming of holes to their final Engineering size, utilizing a two (2) fluted "Dreamer." The Dreamer is a combination drill/reamer bit whose configuration featured a 3/4" length piloted tip and two (2) large land flutes ground to incorporate multiple reamer cutter edges in each of the flute lands. The Dreamer was sized at 0.3770" diameter. Measurement data was accumulated at sixteen (16) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.377987" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point of Engineering tolerance range. All of the holes for this set meet the Engineering criteria.

Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Quackenbush drilling method produces good 23/64" diameter preliminary holes at assembly.

* DRILL METHOD CODING: Q-3 = Quackenbush - One Shot

Quackenbush, air driven power unit driving piloted tip "Dreamer".

3. Quackenbush, air driven power unit driving piloted tip "Dreamer" produces excellent, one step holes to their final Engineering size.

4. Reaming is a feature of the combination drill and reamer bit used in item #3 above.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 464 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.377987", is an ideal characteristic in regard to the Engineering criterion of 0.3770"/0.3790". This is an excellent series of holes on size.

1. Reference to Individual Computer Printout discloses a rather respectable overall measurement range from the highest to lowest reading within the sixteen (16) measurements per hole. The range of measurements are as follows:

Hole #	Range	Hole #	Range
1	0.000526"	16	0.000414"
2	0.000552"	17	0.000879"
3	0.000681"	18	0.000500"
4	0.000457"	19	0.000422"
5	0.000440"	20	0.000395"
6	0.000491"	21	0.000457"
7	0.000483"	22	0.000353"
8	0.000578"	23	0.000569"
9	0.000371"	24	0.000612"
10	0.000560"	25	0.000509"
11	0.000466"	26	0.000422"
12	0.000552"	27	0.000595"
13	0.000552"	28	0.000517"
14	0.000370"	29	0.000526
15	0.000474"		

Focus onto the above measurement ranges was for the purpose of drawing attention to the fact that this series of holes would have been perfect had it not been for extremely slight enlargement at the vicinity of their exit planes induced via subtle chip load build-up.

2. Reference Executive Summary by Data Lot. The range of measurements for this set is 0.000948" as an aggregate series and all measurements are well within the tolerance allowables of 0.3770"/0.3790". Individual Hole Computer Printout discloses the range of measure-

ments to be very good. Only three (3) holes slightly exceeded 0.0006" total ranges and are displayed as follows in increasing order of magnitude:

Hole #	Range
24	0.000612"
3	0.000681"
17	0.000879"

3. Reference to Individual Hole Histograms reveal an excellent dispersion of data elements populated about the mid-range of the hole tolerance zone. A Normal Gausian Distribution representative of this data is suggestive of tools, personnel and processes functioning in complete harmony.

   Reference Executive Summary Histogram.
   The data population is excellent and crowds the mid-range of the tolerance zone. Again, as per the Individual Hole Histograms, a Normal Gausian Distribution is evident signifying controlled hardware processing.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #17 and discloses a value of 0.000741" at plane level #1 on the 0°-90° axes. Enlargement at the entrance plane of measurements most probably is the result of "drill grab" at its start into the hole. The magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality. It disappears at its next plane of measurements.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extemely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90°) to the longitudinal axis of the holes with regard to the skin outside moldline.
The holes are back-spotfaced on the inboard side of the skin to maintain a parallel condition to the skin outer surface moldline.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: This is the most predominant geometric feature of these holes. The bellmouth condition is extremely slight and is apparent generally in the vicinity of the exit planes of the holes. This feature along with its representative hole examples is addressed in the narrative per item III.A.1.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This structure, drilled and reamed through one (1) solid flange was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD - Q1

RANKING NUMBER 10 *

HOLE SIZE 0.312"/0.319"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Rear Spar Upper Attach Fitting. The structure is an aluminum forging whose thickness is 0.310" at the area to be drilled and reamed. The subject hole is sized by Engineering at 0.312"/0.319".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized custom fixturing to assure hole location. Holes were drilled by Quackenbush airpowered drill with automatic feed but non-automatic retract. Drilling was followed by hand-held air feed drill motor powering a piloted reamer. The fitting was reamed while still housed in the assembly fixture. Inspection measurements were obtained by "thru-hole" air probe. Hole drilling and reaming is a combination of custom tooling for drilling and hand reaming.

B. These holes are an excellent example of tools, process and operator skill performing in harmony. All holes within this set are well within the tolerance spread established by Engineering and average overall toward the hole low limit, a desirable feature. Owing to the thickness of the hardware being surveyed three (3) planes of measurements were possible. Additionally, four (4) hole diameter measurements were taken in each plane at axes defined 0^{o}, 45^{o}, 90^{o} and 135^{o}. Upon completion of this set, 348 measurements had been recorded and stored for computer analysis and printout.

* DRILL METHOD CODING: Q-1 = Quackenbush - Hand-held Air Power Reamer

Quackenbush air powered drill w/automatic feed but non-automatic retract. Hand-held air feed drill for reaming.

Refer to the "Executive Summary Printout". The Histogram reveals a Normal Gausian Distribution. The data, grouped tightly together, reveals that all factors, tools, process and operator are contributing to and resulting in excellent hole production.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush drill method and accessories producing good holes.

3. Hand held air powered drill motor utilizing a piloted reamer produces good final sizing of this set of holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. CHARACTERISTICS:

A. Hole Size: All holes were within the allowable Engineering criterion of 0.312"/0.319". Holes were individually excellent on size with the average of all 348 recordings being 0.313338". Only 0.001060" separated the highest recording (0.313931" at Hole #16) from the lowest recording (0.312871" at Hole #10).

B. Ovality: Maximum recorded ovality within the set was 0.000293" at Hole #15. It occurred to the exit side of the hole. Cause of the slight ovality is extremely subtle breakout loading on the hole.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined

III. C. (Continued)

face (inter-face surface). Perpendicularity was verified to be zero degrees (0^o) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD SE

RANKING NUMBER 11 *

HOLE SIZE: 0.246"/0.250"

I. OVERVIEW:

A. This set of survey holes features Spacematic drilling, cold-work split-sleeve/mandrel expansion and final hand reaming of holes in a Center Wing Lower Surface, along the Center Spar. The structure is an all aluminum stack consisting of the lower surface wing skin panel and the center spar cap. The approximate thickness in the area surveyed was 0.60".

The subject hole is sized by Engineering at 0.235"/0.238" as the starting hole for cold-working per specification and the final ream size at 0.246"/0.250" per Specification.

The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Assist tooling such as hand-held stand-off reamer guide bushing to stabilize hand-held air motors, reamer and the technician during the duty cycle of reaming was used. In addition, a siphon fed air-mist coolant system is employed during drilling/reaming to obvious and product quality advantage. The location of the holes of this set were selected purposely for their disadvantaged location behind a tooling post on the assembly fixture to compare final hole quality to that of subsequent lots of holes in more accessible areas.

* DRILL METHOD CODING: SE = Spacematic with Expansion Spacematic drilling, cold-work split sleeve/mandrel expansion. Final hand reaming.

II. SUMMARY

A. Reference Executive Histogram by Data Lot. The data population for this set is densely situated about the 0.2470"/0.2472" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a Bimodal Gausian Distribution that is significant in concluding a manufacturing sequence where the tools, process and personnel are functioning harmoniously and yield a quality end product.

Twenty-nine (29) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.247200" for the series of twenty-nine (29) holes. This value is excellent since it resides at the low limit vicinity of the tolerance range. The affect of adequate and proper use of tooling and craftsmanship are apparent in this set of holes.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Spacematic preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Hand-held air powered drill motor driving a piloted tip reamer produces very good final holes per 0.246"/0.250" tolerance criterion.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2375" (tip) and 0.2470" (shank).

3. The affect of a hand-held stand-off, reamer guide bushing tool to assist in stabilizing the reamer and powerhead is apparent in the shape and quality of the final holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1044 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference "Executive Summary by Data Lot" discloses an arithmetical average of 0.247200" which is excellent for the set and is reflected in the quality of the holes.

An extremely slight bellmouth characteristic is the only geometric feature departing from otherwise excellent cylindrical holes.

All of the specimens conform to the tolerance criterion established by Engineering.

1. Seven (7) holes, identified Hole #6, 13, 14, 19, 20, 24 and #27 are nearly perfect specimens. Less than 0.0003" variation exists in the series of thirty-six (36) measurements recorded for each individual hole.

Reference Individual Hole Computer Printouts. The range of measurements for the above holes were recorded as follows:

Center Wing

Hole #	Range	Hole #	Range
6	0.000069"	20	0.000216"
13	0.000138"	24	0.000233"
14	0.000293"	27	0.000267"
19	0.000199"		

Holes #14, 24 and #27 reveal an exceedingly slight "spur" in the vicinity of the top portion of the

holes which most probably is a result of chip load irregularity. It is not considered a detriment to hole quality and is not perceptible via visual inspection of the specimens at 3X magnification.

2. Nine (9) holes, identified Hole #5, 7, 10, 12, 17, 18, 21, 22 and #23 are virtually the same as item #1 above except that all of these specimens exhibit a bellmouth feature at either their entrance or exit vicinities of the holes. The characteristic is extremely slight and where it occurs at the entrance to the hole (#7, 18, 21, 22 and #23) it is suggestive of center-seeking of the reamer. The feature is insignificant and not considered a detriment to overall hole quality. On the specimens where the feature occurs at the exit plane of the hole (#5, 10, 12 and #17), the most probable cause is chip build up from the start of coolant starvation during the duty cycle of reaming. The magnitude of the characteristic is extremely small, at less than 0.0005" and is therefore no cause for concern on hole quality degradation.

3. Holes #16 is the largest hole of the set and recorded its greatest measurement at 0.248684". Reference Individual Hole Computer Printout reveals the feature to be a result of side-loading by the operator during the reaming duty cycle. The characteristic is predominant along the lower portion of the 90° and 135° Axes. Accidental tipping/roll-over of the hand-held reamer guide bushing most probably resulted in the enlargement of the hole along the 90-135° Axes.

4. Holes #2 exhibits an enlargement along its 45° and 90° Axes, but remains within the allowable Engineering tolerance. The most probable cause for the adjacent axis lobing is side-loading during reaming, possibly due to the inaccessible location of the hole.

5. All of the features noted in items III.A.1 through III.A.4 are considerably slight as a departure from a truly cylindrical hole. This series of holes were selected for measurement and profile analysis owing to the fact that they are predominately

behind a <u>fixture post</u> and were more difficult to approach from an accessibility standpoint. Regardless, the use of assist tooling for stabilizing the powerhead, reamer and operator is apparent in the data. The overall quality of this series of holes is very good. The fact that <u>all</u> of the holes are within tolerance attest to the craftsmanship, skill and knowledgeable use of tooling.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #16 and discloses a value of 0.001241" on the 0^{o} - 90^{o} axes at plane #7. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the side-load feature in this hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (generally less than 0.0004"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2^{o}.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by holes referenced in III.A.1 thru III.A.5 narrative.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture. Several holes revealed a very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at

3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 12 *

HOLE SIZE: 0.199"/0.202"

I. OVERVIEW:

This set of production holes features drilling and reaming of a Drag Brace Assembly. The structure is a multi-layered stack of steel, aluminum and titanium members whose combined thickness in the area to be surveyed is approximately 0.75". The subject hole is sized by Engineering at 0.199"/0.202" for installation of Huck Blind Bolts.

Drill:	0.1908: diameter, #A51X20170-1
Reamer:	0.1998" diameter, #A51X40069-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	555 Crystal Cut @ 10:1 Water Mix

Info: Drilling and reaming were performed in the direction of the steel member through to the titanium parts. Inspection utilizes plug "Go" and blade "No-Go" gaging method.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy leaf drill plate, integral to the nacille drag brace fixture to facilitate locking on the Quackenbush, air driven drill power head. Hand fed Crystal Cut 555 coolant and air were used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.1908" and followed by Quackenbush, air driven drill motor and 0.1998" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.200694" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the goemetric characteristics of the holes are discussed at paragraph III.

* DRILL METHOD CODING: Q-2 = Quackenbush - Air Power, Reamer, Mechanical

Quackenbush, air powered drill & accessory tooling.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.1908" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.1998" reamer.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" Gaging inspection.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 1044 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.200694", well below the 0.2020" high limit per established Engineering Criterion. This is an excellent series of holes on size; however, a "barrelled" characteristic is apparent in the aluminum part which is sandwiched between the steel and titanium members at the assembly stack.

Reference Computer Individual Hole Printout discloses an excellent range distribution of hole measurements considering the material differences within the stack and the depth (0.75") of the drilled/reamed holes.

1. The spread of measurements taken at thirty-six (36) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000567"	16	0.000440"
2	0.000553"	17	0.000267"
3	0.000561"	18	0.001026"
4	0.000569"	19	0.000500"
5	0.000557"	20	0.000509"
6	0.000474"	21	0.000495"
7	0.000612"	22	0.000374"
8	0.000468"	23	0.000763"
9	0.000463"	24	0.000422"
10	0.000424"	25	0.000405"
11	0.000694"	26	0.000406"
12	0.000397"	27	0.000500"
13	0.000715"	28	0.000483"
14	0.000431"	29	0.000466"
15	0.000842"		

Note: Only one (1) hole, identified Hole #18 reached a range spread value of 0.001". The reader is reminded of the fact that the range of measurements for each hole includes the "barrelling" feature which is present in the aluminum "sandwiched" detail part.

2. Reference Individual Hole Computer Profiles. Hole #2,#5,#7,#11 and #15 are representative examples of a barrelling in holes. It is not an uncommon feature when the stack-up exhibits steels and/or titanium in the lay-up. Titanium chip migration back through the softer aluminum causes the barrelled condition which is inherent in most of the holes . The subject holes including the barrelled condition do not exceed the tolerance criterion established by Engineering.

3. Individual Histograms disclose a relatively Normal Gausian Distribution on the measurement population and all are grouped in the vicinity of the mid-point tolerance range. The Executive Histogram for the entire data set discloses two peak areas. Responsibility for the peak shift is geometry changes in the assembly owing to taper in the material stack per Engineering design.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #18 and recorded at 0.000819" at Level #9 on the 0^{o}-90^{o} axes. This value is negligible to hole quality since it does not exceed the tolerance permitted by Engineering. This ovality spike most probably resulted from coolant starvation and chip build-up just prior to exiting the hole. There are no other holes of the set featuring this condition.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, 0.199"/0.202" would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: A subtle "barrelling" feature is inherent in all holes of this series; however, <u>none</u> of the holes of this set exceed the Engineering tolerance as a result of their barrelled feature. This characteristic is an anticipated feature when aluminum is "sandwiched" in the lay-up between steels, titanium and/or other substantially harder materials. Refer to Individual Computer Profile Printout and Axis Measurements for the magnitude of the barrelled conditions. Refer also to item III.A.1 and III.A.2 for related information.

F. Bellmouthing: None evident per profile analyses. The stacking arrangement of the detail parts exhibiting steel and titanium as their outer laminates is a deterrent to the formation of bellmouthing when accompanied by heavy fixturing and sharp, well maintained accessory tools.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-3

RANKING NUMBER 13 *

HOLE SIZE: 0.5645"/0.5675"

I. OVERVIEW:

A. This set of production holes features a one (1) operation drill and reaming of a Wing Splice Installation. The structure at the wing root is an aluminum forging whose thickness is 0.540" constant along WS 110.00. The subject hole is sized by Engineering at 0.5645"/0.5675" for installation of 9/16" (MS21250-09022 bolts).

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production featured Quackenbush single step drill and reaming of holes to their final Engineering size, utilizing a two (2) fluted "Dreamer." The Dreamer is a combination drill/reamer bit whose configuration featured a 3/4" length piloted tip and two (2) large land flutes ground to incorporate multiple reamer cutter edges in each of the flute lands. The Dreamer was sized at 0.5645" diameter. Measurement data was accumulated at twenty-eight (28) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.565673" for the set of twenty-nine (29) holes. This value is a very good feature since it resides at the mid-point of Engineering tolerance range. All of the holes for this set meet the Engineering criteria.

Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Quackenbush, air driven power unit driving piloted tip "Dreamer" produces excellent, one step holes to their final Engineering size.

3. Reaming is a feature of the combination drill and reamer bit used in item #2 above.

* DRILL METHOD CODING: Q-3 = Quackenbush - One Shot Quackenbush, air driven power unit driving piloted tip "Dreamer".

4. **Planning is very good, providing adequate work instructions and definition of inspection requirements.**

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 812 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.565673", is an ideal characteristic in regard to the Engineering criterion of 0.5645"/0.5675". This is an excellent series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Six (6) holes are nearly perfect with their spread of twenty-eight (28) measurements per hole having recorded less than 0.0004" variation as follows:

Hole #	Range	Hole #	Range
1	0.000379"	12	0.000328"
3	0.000371"	18	0.000276"
11	0.000371"	23	0.000293"

2. Arbitrarily increasing the range spread to allow a total range spread of less than 0.0006" permits entry of sixteen (16) additional specimens into the select category of excellent holes. Their identification and range spread values are as follows:

Hole #	Range	Hole #	Range
2	0.000517"	16	0.000526"
4	0.000405"	19	0.000552"
5	0.000526"	20	0.000448"
6	0.000526"	22	0.000560"
9	0.000569"	24	0.000500"
13	0.000431"	26	0.000552"
14	0.000405"	27	0.000569"
15	0.000517"	28	0.000466"

3. Reference Executive Summary by Data Lot. The range of measurements for this set is 0.001328" as an aggregate series and <u>all</u> measurements are well within the tolerance allowables of 0.5645"/0.5675". <u>Individual Hole Computer Printout</u> discloses the range of measurements to be very good with the maximum value at 0.000776" occurring within Hole #8.

Only three (3) holes of the set exhibited range values at the 0.0007" figure. They are displayed as follows in increasing order of magnitude:

Hole #	Range
17	0.000716"
21	0.000733"
8	0.000776"

4. Reference Individual Hole Computer Printouts. The only geometric characteristic detracting from otherwise excellent holes is identified by analysis as chip spurs and chip load occurring <u>inside</u> the holes. The features are extremely subtle and <u>not discernible</u> except via Hole Profile Printout.

   a. Representative examples of chip spurring are exhibited by Holes #8,#9,#16,#17 and #25. The spikes are evident generally deep inside the affected holes and at varying measurement levels. Refer to plane levels #4 and #5 for Hole #8 disclosure. These spike traces occur similarly at the other referenced examples but at varying levels.

   b. Representative examples of chip load build-up hole enlargement are exhibited by Holes #7,#10, #16,#19 and #28. The "bulges" resulting from chip build-up express themselves as <u>barrelling</u> inside the holes via data analysis. Refer to the Individual Hole Profiles for graphic evidence of this phenomenon. At <u>worst case</u>, the feature is very subtle as evident in the measurement traces of the holes, their range spread and profiles which are expressed as <u>diameter</u> variations.

5. Reference to Individual Hole Histograms reveal an excellent dispersion of data elements populated about the mid-range of the hole tolerance zone. A Normal Gausian Distribution representative of this data is suggestive of tools, personnel and processes functioning in complete harmony.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #29 and discloses a value of 0.000647" at plane level #7 on the 45°-135° axes. Enlargement at the exit plane of measurements most probably is the result of irregular breakout occurring at the completion of drill/reaming. The magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90°) to the longitudinal axis of the holes with regard to the drilled/reamed wing root forging structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: This feature along with its representative hole examples is addressed in the narrative per item III.A.4.b.

F. Bellmouthing: None existent as evidenced by profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This structure, drilled and reamed through one (1) solid flange was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 14 *

HOLE SIZE: 0.250"/0.253"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Longeron Installation, Fuselage Mid-Section.

The structure is a multilayered stack approximately 1.00" thick in the areas to be surveyed. The subject hole is sized by Engineering at 0.250"/0.253" for installation of KA8 (NAS1054-8) HiShear Rivets.

B.

Holes 1 through 17

Drill:	0.2344" Diameter, #P118891-1
Reamer:	0.2502" diameter, #P118892-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	HE-2 @ 10.1 Water Mix

All parts in the stack are alumium.

Drill:	0.2344" diameter, #P-195240-1 Coredrill
Reamer:	0.2500" diameter, #P-118894-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	J-1 Brush On

Note: Inspection utilizes plug "Go" and blade "No-Go" gaging method.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power, Reamer Mechanical

Quackenbush, air powered drill & accessory tooling.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized heavy drill plates, pinned and clamped to the assembly fixture to facilitate locking on the Quackenbush, air driven drill power head. Hand brush-on and Squeeze Bottle HE-2 coolant was used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.2344" and followed by Quackenbush, air driven drill motor and 0.2500"/0.2502" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.250575" for the set of twenty-nine (29) holes. This value is an ideal feature since it resides at the low-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes.

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.2344" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.2502" reamer for Holes #1 through #17 and a 0.2500" reamer for Holes #18 through #29.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" Gaging inspection.

III. CHARACTERISTICS:

A. Hole Size: 1156 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.250575", well below the 0.2530" high limit per established Engineering Criterion. This is an exceptional series of holes on size and other geometric characteristics disclosed via computer printout and profiles.

Reference Computer Individual Hole Printout discloses an excellent range distribution of hole measurements considering material thicknesses within the stack resulting in a (1.00") depth for the drilled/reamed holes.

1. The spread of measurements taken at forty (40) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000379"	16	0.000263"
2	0.000207"	17	0.000203"
3	0.000431"	18	0.000345"
4	0.000172"	19	0.000302"
5	0.000871"	20	0.000345"
6	0.000647"	21	0.000483"
7	0.000302"	22	0.000233"
8	0.000293"	23	0.000319"
9	0.000190"	24	0.000198"
10	0.000327"	25	0.000233"
11	0.000302"	26	0.000336"
12	0.000216"	27	0.000397"
13	0.000226"	28	0.000198"
14	0.000225"	29	0.000319
15	0.000192"		

Note: Only two (2) holes, identified Hole #5 and #6 exhibit a range of measurements that exceeded 0.0005" over the forty (40) measurements per hole.

2. Holes #5 and #6 exhibit the greatest range in measurement spread at 0.000871" and 0.000647" respectively. Additionally, both feature a bellmouth and/or taper condition that is unique to these holes only when compared to the other holes in the series. Both holes are from the group in the all aluminum material stack-up. Chip build-up load and galling due to coolant starvation is suspected as cause for bellmouthing/taper in both holes. Drill and reamer stall was observed on the opposite hand assembly due to coolant omission; thus, it is the most probable cause for the slight bellmouth enlargement. Both holes,however, including the slight bellmouth, are well within the tolerance established by Engineering.

3. Individual Hole Histograms disclose a Normal Gausian Distribution on measurement population, providing conclusive evidence of process, tooling and personnel performing in perfect harmony.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #27 and recorded at 0.000220" at Level #3 on the 45°-135° axes. This value is negligible on hole quality. A faying surface interface from steel to aluminum occurs at this level thus resulting in an ovality enlargement of the hole.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90^{o}) to the longitudinal axis of the holes with regard to the drilled/reamed longeron structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: On the all aluminum stack-up holes, Hole #5 and #6 exhibit a slight bellmouth condition. Reference individual hole computer printout for profile and magnitude. Refer to item III.A.2 for cause.

On the steel/aluminum holes (Holes #18 through #29), Holes #21 and #26 exhibit an extremely slight bellmouth feature at the top of the hole (steel part). On these holes, bellmouthing is so slight it is not construed by this analysis as a quality defect in the holes. All holes are well within the Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were only slight perceptible rifling traces on the hole side-walls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "100 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 15 *

HOLE SIZE: 0.190"/0.194"

I. OVERVIEW:

A. This set of production holes features freehand drilling and reaming of the Skin Installation.

The structure is all aluminum approximately 0.37" thick in the area being surveyed. The subject hole is sized by Engineering at 0.190"/0.194" for installation of 3/16" NAS 1581A3 fasteners.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production was freehand drilling and reaming. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.190412" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the extreme low vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Freehand air powered drilling and hand held drill guide bushing produces very good preliminary holes.

3. Freehand reaming using a piloted reamer and handheld guide bushing results in excellent final sized holes.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

* DRILL METHOD CODING: H-2 = Hand-held drill and Reamer Freehand air powered drilling and hand-held drill guide bushing; freehand reaming using a piloted reamer and hand-held guide bushing.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 580 data entries were accrued for the series of holes. The arithmetical average for the set is 0.190412", well below the 0.194" high limit per established Engineering Criterion. This is an excellent series of holes on size and shape features especially considering the fact that all operations were freehand. The most predominant geometric feature traceable to the method of production is extremely slight taper and/or bellmouth at the entrance vicinities of several holes attributable to center-seeking on the reaming. The feature exists but is well within the tolerance per Engineering Criterion.

1. Basic hole size was extremely consistent as evidenced by the range measurements of the set. Range also is the predominant factor in determining hole shape for this set. A series of measurements taken at twenty (20) locations within each hole were as follows:

Hole #	Range	Hole #	Range
1	0.000664"	16	0.000379"
2	0.000620"	17	0.000397"
3	0.000431"	18	0.000526"
4	0.000619"	19	0.000391"
5	0.000319"	20	0.000508"
6	0.000556"	21	0.000216"
7	0.000397"	22	0.000319"
8	0.000491"	23	0.000405"
9	0.000642"	24	0.000716"
10	0.000560"	25	0.000690"
11	0.000595"	26	0.000520"
12	0.000336"	27	0.000417"
13	0.000517"	28	0.000397"
14	0.000357"	29	0.000293"
15	0.000189"		

2. Reference item III.A.1. and Individual Hole Computer Printouts. Twelve (12) holes, identified Hole #5,#7, #12,#14,#15,#16,#17,#19,#21,#22,#28 and #29 are nearly perfect specimens whose total range is less than 0.000400". Operator comfort on the drill/reaming task brought about via fixturing (the structure is approximately waist high) and direction of drill/reaming, nearly straight down the gravity vector is definitely an asset to hole quality and geometry. Operator skill must also be recognized as a factor to hole quality on this set.

3. Reference item III.A.1. and Individual Hole Computer Printouts. Four (4) holes, identified Hole #3,#10, #26 and #27 are closely related to nearly perfect holes. Slight chip spur gouges are evident per computer data inside the holes, but are not perceptible to the naked eye as a flaw characteristic in the holes. The conditions within each hole are well within the criterion set per Engineering tolerance. The range on these holes was recorded at 0.000431", 0.000560", 0.000520" and 0.000417" respectively.

4. Center-seeking is evident in Holes #1,#2,#4,#6,#13, #18,#20,#23 as exhibited in the Individual Hole Computer Profile Data. It is extremely subtle and considered a normal phenomenon on freehand drilling/reaming and results in very slight bellmouth and/or taper.

5. Side-loading induced via operator instability is also a normal feature expected in freehand operations; however, owing to the ideal work position on this set, only three holes identified Hole #8,#9 and #11 disclose a very subtle side-load affect and range variation was only 0.000491", 0.000642" and 0.000595" respectively.

6. Reference Individual Hole Histograms generally disclose a Normal Gausian Distribution with the data populated closely together. The "center-seeking" feature described in III.A.4. is accountable for the data distribution on the Executive Summary Histogram for this set exhibiting a spread covering a 0.001000" range between 0.190" and 0.191". This spread magnitude is not uncommon in freehand operations such as in this set.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #6 and recorded at 0.000556" at Level #1 on the 45^{o}-135^{o} axes. This value is negligible and does not cause quality degradation of the hole. Ovality was a function of an erratic start in reaming brought about via subtle operator side load.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90^{o}) to the longitudinal axis of the holes.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile Analyses.

F. Bellmouthing: This characteristic has been addressed per narrative at item III.A. and III.A.4. The feature is extremely slight and does not violate the tolerance criterion established per Engineering.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING METHOD 16 *

HOLE SIZE: 0.250"/0.253"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Drag Brace Assembly. The structure is a multi-layered stack of steel, aluminum and titanium members whose combined thickness in the area to be surveyed is approximately 0.75". The subject hole is sized by Engineering at 0.250"/0.253" for installation of Huch Blind Bolts.

B.

Drill:	0.2344" diameter, #A51X40289-1
Reamer:	0.2508" diameter, #A51X20127-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	555 Crystal Cut @ 10:1 Water Mix
Info:	Drilling and reaming were performed in the direction of the steel member through to the titanium parts. Inspection utilizes plug "Go" and blade "No-Go" gaging method.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy leaf drill plate, integral to the nacelle drag brace fixture to facilitate locking on the Quackenbush, air driven drill power head. Hand fed Crystal Cut 555 collant and air were used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.2344" and followed by Quackenbush, air driven drill motor and 0.2508" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.251581" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point vicinity of the Engineering tolerance range. <u>All</u> of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical

Quackenbush, air powered drill and accessory tooling.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.234" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.2508" reamer.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" Gaging inspection.

III. CHARACTERISTICS:

A. Hole Size: 1160 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.251581", well below the 0.2530" high limit per established Engineering Criterion. This is an excellent series of holes on size; however, a "barrelled" characteristic is apparent in the aluminum part which is sandwiched between the steel and titanium members at the assembly stack.

Reference Computer Individual Hole Printout discloses an excellent range distribution of hole measurements considering the material differences within the stack and the depth (0.75") of the drilled/reamed holes.

1. The spread of measurements taken at forty (40) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000698"	16	0.001086"
2	0.001274"	17	0.000622"
3	0.000621"	18	0.000585"
4	0.000543"	19	0.000685"
5	0.000954"	20	0.000707"
6	0.000783"	21	0.000741"
7	0.000625"	22	0.000888"
8	0.000731"	23	0.000862"
9	0.000448"	24	0.000914"
10	0.000469"	25	0.000830"
11	0.001345"	26	0.000804"
12	0.000490"	27	0.000774"
13	0.000497"	28	0.000681"
14	0.000538"	29	0.000697"
15	0.000527"		

Note: Only three (3) holes, identified Hole #2,#11 and #16 reveal a range value that exceeds 0.001". The reader is reminded of the fact that the range of measurements for each hole includes the "barrelling" feature which is present in the aluminum "sandwiched" detail part.

2. Holes #2,#11,#16,#22,#23 and #24 reveal slightly larger profile patterns on the "barrelling" characteristic than are apparent on the remainder of the holes in the series. Chip load migration of the titanium back through the aluminum coupled with slight coolant starvation producing heat-up is suggested as most probable cause for the enlarged "barrelling" profiles which at the worst case are still well within the Engineering tolerance criterion.

3. Individual Histograms disclose a relatively Normal Gausian Distribution on the measurement population and all are grouped in the vicinity of the mid-point tolerance range. The Executive Histogram for the entire data set discloses two peak areas. Responsibility for the peak shift is geometry changes in the assembly owing to taper in the material stack per Engineering design.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #16 and recorded at 0.000371" at Level #2 on the 0°-90° axes. This value is negligible on hole quality. A faying surface interface from steel to aluminum occurs at this level thus resulting in an ovality enlargement of the hole.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90°) to the longitudinal axis of the holes with regard to the drilled/reamed nacelle structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: A subtle "barrelling" feature is inherent in all holes of this series except Holes #9 and #10. The characteristic is an anticipated feature when aluminum is "sandwiched" in the lay-up between steels, titanium and/or other substantially harder materials. Refer to Individual Computer Profile Printout and Axis Measurements

for the magnitude of the barrelled conditions. Refer also to item III.A.1 and III.A.2 for related information.

F. Bellmouthing: None evident per profile analyses. The stacking arrangement of the detail parts exhibiting steel and titanium as their outer laminates is a deterent to the formation of bellmouthing when accompanied by heavy fixturing and sharp, well maintained accessory tools.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 17 *

HOLE SIZE: 0.312"/0.315"

I. OVERVIEW:

A. This set of production holes features "one-shot" drilling and counter-sinking of the Wing Upper Surface.

The structure is an assembly of aluminum skin and stringers whose thickness is approximately 0.38" in the areas being surveyed. The subject hole is sized by Engineering at 0.312"/0.315" for installation of NAS1580A, Flush Head High Shear Bolts located aft of the front spar.

II. SUMMARY:

A. Twenty-nine (29) holes were surveyed from one (1) available assembly on the factory line. The method of production utilized the Spacematic air driven power head for drilling and counter-sinking. Spray-mist coolant integrally coupled to the powerhead provided adequate cooling during the duty cycle of the drill, and drill stalls were not noted during the processing of this series of holes. Measurement data on the holes was accomplished via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.313416" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling producing satisfactory "one-shot" full sized holes at assembly.

3. Reaming was not a requirement for the holes at this work station.

* DRILL METHOD CODING: S-1 = Spacematic - One Shot No reaming. Spacematic, air powered drill and accessory tooling.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

III. CHARACTERISTICS:

A. Hole Size: 580 data entries were accrued for the series of holes. The arithmetical average for the set is 0.313416", well below the 0.315" high limit per established Engineering Criterion. This is a very good series of holes on size but are characteristically tapered and/or bell-mouthed. The most predominant geometric feature traceable to the method of production is slight taper and/or bellmouth at the exit plane vicinities of the majority of the holes, attributable to drill chip build-up. The feature exists but is well within the tolerance per Engineering Criterion.

1. Range measurement values are the predominant factor in determining hole shape for this set. A series of measurements taken at twenty (20) locations within each hole were as follows:

Hole #	Range	Hole #	Range
1	0.000301"	16	0.000293"
2	0.000483"	17	0.000466"
3	0.000724"	18	0.000388"
4	0.000741"	19	0.000583"
5	0.000526"	20	0.000319"
6	0.001278"	21	0.000690"
7	0.000617"	22	0.000500"
8	0.001753"	23	0.000532"
9	0.000413"	24	0.000431"
10	0.000523"	25	0.000478"
11	0.000583"	26	0.000586"
12	0.000560"	27	0.000491"
13	0.000428"	28	0.000371"
14	0.000337"	29	0.000529"
15	0.000353"		

2. Reference item III.A.1. and Individual Hole Computer Printouts.
Six (6) holes, identified Hole #1,#14,#15,#16,#20 and #28 are nearly perfect specimens. There are no flaw features evident in the computer data nor apparent in the physical holes via 3X magnification by Sight Pipe inspection.

3. Reference Individual Hole Computer Printouts. All other holes of this set (item III.A.2 excepted), exhibit the taper and/or bellmouth characteristic. All of the specimens are well within the tolerance criterion established per Engineering and the feature at worst case is only 0.001278" in magnitude at Hole #6 and 0.001753" at Hole #8.

4. The Histograms, both Summary by Lot and Individual, reflect a data population at the mid range of the tolerance band. The taper built into the holes via chip influence is extremely slight and has negligible affect on hole overall quality.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #8 and recorded at 0.000603" at Level #3 on the 45^{o}-135^{o} axes. Ovality in this hole results from slight tapered condition resulting from chip build up enlargement of the exit vicinity of the hole.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90^{o}) to the longitudinal axis of the holes.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile Analyses.

F. Bellmouthing: This characteristic has been addressed per narrative at item III.A, and III.A.3. The feature is extremely slight and does not violate the tolerance criterion established per Engineering.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 18 *

HOLE SIZE 0.250"/0.253"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Vertical Fin Attach Fitting. The structure is aluminum skin (0.160") to a titanium fitting 0.100" thick at the surface to be drilled and reamed. The hole being inspected is sized at 0.250"/0.253" by Engineering.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The material, a combination of aluminum skin to titanium fitting was inspected by "thru-hole" air probe. Measurements were taken by air probe penetration from inside the structure and progressing outboard toward the outer skin. In the sequence of measurements on the Statistical Printout, the first series of four (4) readings are the holes in the titanium fitting. The second series are measurements in the aluminum skin.

The computer data Statistical Printout for this series of holes provides a composite traceable to the following for the production of good holes:

1. Custom fixturing was not required to locate the holes.

2. Hand held drill/reaming method and accessories were adequate to produce a good set of holes.

3. Planning is excellent for inspection traceability on holes.

4. Good tooling on a planned periodic refurbish program, coupled with the mandatory requirement for technician

* DRILL METHOD CODING: H-2 = Hand Held Drill and Ream Hand-held drill/reaming and accessories.

II. 4. (Continued)

to draw new and/or currently refurbished/reinspected drills and reamers from production tool cribs for use on the job is evident in product quality.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: All holes were within the allowable Engineering criterion of 0.250"/0.253". Holes are individually excellent on size. Measurements taken at 8 locations within each hole yield an average value of 0.251153".

Holes #24 and #25 disclose an undersize condition at the second plane of measurements. This plan is in the aluminum skin and is suggested by the Survey Team as an error caused by blockage of the "air probe" orifice. It is concluded that a particle of sealant and/or sealant extruded into the hole at the interface of the fitting to skin resulted in erroneous readings. Discounting the affected readings on Holes #24 and #25 and substituting the next lowest reading from the measurements of all holes results in the following:

Reading 0.252207" @ Hole #23 (Highest)
Reading <u>0.250552"</u> @ Hole #21 (Lowest)
0.001655"

The Range of the set therefore is 0.001655" in lieu of 0.002828".

The trend in measurements is indicative of tooling producing ideal holes since the yield of all measurements provides an average size of 0.251153", tending toward the midpoint of the tolerance spread.

B. Ovality: Maximum recorded ovality within the set was 0.000741" at Hole #20. Individual holes within this set (8 measurements per hole) ranged to as low as 0.000017" at Hole #15.

The cause for the slight ovality within this set of holes is considered the result of instability on the hand held bushing guide for reaming. Ovality is predominately at the start (entrance) to the hole, and is very slight. Ref. Computer Printout.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined face of the Vertical Fin Attach Fitting. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Very slight as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed by hand method and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-2

RANKING NUMBER 19 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling of the Rear Spar Lower Surface, between Wing Stations 45.5" and 66.0". The structure is an all aluminum stack whose approximate thickness in the area to be surveyed is 0.625". The subject hole is sized by Engineering at 0.2460"/0.2500" for installation of Hi-Lok flush head bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. All Holes of this series are in complete compliance with all Engineering tolerance criterion. Measurement data was accumulated at twenty-eight (28) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.247135" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the low-point vicinity of the Engineering tolerance range. Specific discussion on the geometric characteristics of the holes are discusses in paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces very good preliminary holes at assembly.

* DRILL METHOD CODING: S-2 = Spacematic - Hand-held, reaming. Spacematic, air powered drill and accessory tooling.

3. Hand-held, air powered drill driving a piloted reamer achieves final hole size per Engineering.

4. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 809 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.247135" as evidenced per the Executive Summary by Data Inc. All of the holes of this series comply with all Engineering tolerance criterion.

1. Reference Executive Summary Histogram. Only three (3) holes, identified Hole #27, #28 and #29 disclosed measurement series in the range of 0.248000". The population of data about 0.247000" exhibits a Normal Gausian Distribution. This feature is representative of Holes #1 through #26 of this set and is indicative of tools, process and personnel functioning in harmony.

The data elements centered about the 0.248000" zone are representative of Holes #27, #28 and #29. These also are excellent holes with no specific cause identifiable for their slight size difference.

2. There are no detrimental characteristics suggesting a degradation of hole quality in the holes as evidenced by Individual Computer Printout for each Hole.

3. Six (6) holes, identified Hole #5, #6, #7, #19, #20 and #22 per Individual Computer Printout reveal an extremely small bellmouth and/or taper condition at their start plane of drilling. The condition is negligible as evidenced by their measurement distribution as follows:

Hole #	Total Measurement Range
5	0.001043"
6	0.000784"
7	0.000836"
19	0.000537"
20	0.000440"
22	0.000509"

All of these holes are well within the Engineering tolerance criterion. Slight wobble at start of drilling is suggested as cause for the minute bellmouth feature in these holes.

4. The range of data from the lowest to the highest reading among twenty-eight (28) measurement points for this series of holes is worthy of recap. Specific data for each hole is presented on the Individual Hole Computer Printout. The range of measurements were as follows:

Hole #	Range	Hole #	Range
1	0.000431"	16	0.000302"
2	0.000422"	17	0.000397"
3	0.000388"	18	0.000216"
4	0.000293"	19	0.000537"
5	0.001043"	20	0.000440"
6	0.000784"	21	0.000233"
7	0.000836"	22	0.000509"
8	0.000250"	23	0.000319"
9	0.000250"	24	0.000463"
10	0.000259"	25	0.000345"
11	0.000250"	26	0.000302"
12	0.000224"	27	0.000259"
13	0.000457"	28	0.000314"
14	0.000259"	29	0.001060"
15	0.000267"		

B. Ovality: Maximum recorded ovality within the set occured at Hole #29 and recorded at 0.000759" at Level #1 on the 45^{o}-135^{o} axes. The ovality feature of Hole #29 is directly related to the bellmouth condition at its start plane.

Ovality is not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Hole #13 Individual Profile reveals an extremely shallow barrelling feature. Chip load is suspected as the cause for the geometric configuration of this hole. The specimen is an excellent hole regardless of the barrelling characteristic which does not exceed the Engineering tolerance allowable.

F. Bellmouthing: Evident in very subtle amounts as indicated by Holes referenced at item III. A.3. Various other holes of this set exhibit the same condition at their entrance plane of drilling but to a much smaller value.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was no evidence of rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-3

RANKING NUMBER 20 *

HOLE SIZE: 0.3775"/0.3805"

I. OVERVIEW:

A. This set of production holes features a one (1) operation drill and reaming of a Wing Splice Installation. The structure at the wing root is an aluminum forging whose thickness is 0.420". The subject hole is sized by Engineering at 0.3775"/0.3805" for installation of 3/8" (LWB22-6-16 bolts).

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production featured Quackenbush single step drill and reaming of holes to their final Engineering size, utilizing a two (2) fluted "Dreamer." The Dreamer is a combination drill/reamer bit whose configuration featured a 3/4" length piloted tip and two (2) large land flutes ground to incorporate multiple reamer cutter edges in each of the flute lands. The Dreamer was sized at 0.3775" diameter. Measurement data was accumulated at twenty-four (24) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.377870" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the low-point of Engineering tolerance range. All of the holes for this set meet the Engineering criteria.

Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Quackenbush, air driven power unit driving piloted tip "Dreamer" produces excellent, one step holes to their final Engineering size.

3. Reaming is a feature of the combination drill and reamer bit used in item #2 above.

* DRILL METHOD CODING: Q-3 = Quackenbush - One shot
Quackenbush, air driven power unit driving a piloted tip "Dreamer".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 696 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.377870", is an ideal characteristic in regard to the Engineering criterion of 0.3775"/0.3805". This is an excellent series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Twelve (12) holes are nearly perfect with their spread of twenty-four (24) measurements per hole having recorded less than 0.0003" variation as follows:

Hole #	Range	Hole #	Range
1	0.000276"	8	0.000103"
2	0.000164"	13	0.000082"
3	0.000233"	15	0.000207"
4	0.000241"	16	0.000291"
5	0.000276"	17	0.000088"
6	0.000276"	18	0.000143"

2. The remainder of the holes comprising the series comply with all Engineering tolerance criterion on size and shape. Reference Executive Summary Histogram. The data population discloses a spike at the vicinity of 0.377600". The spike is representative of most of the data from individual hole measurements. Cause for the data distribution flattening between the 0.378000" and 0.379000" range is a function of the features described in item III.A.3.a. and III.A.3.b.

3. Reference Individual Hole Computer Printout. The only characteristics detracting from otherwise excellent holes are identified as follows:

   a. Bellmouth and/or taper at the entrance vicinity of the holes. Holes #10,#11,#19,#20 and #21 are representative samples.

      The cause for the taper featured at the start plane of the holes is suggestive of minor Dreamer "seeking" of the tip on drill entry since the oval feature is <u>rather uniform</u> at all axes of measurement.

b. Occasional chip spikes are also apparent in isolated cases. Holes #12,#21,#24 and #27 are representative specimens. The condition is extremely subtle and is not construed via analysis as a detriment to overall hole quality.

None of the conditions referred to in item "a" or "b" above exceed the Engineering tolerance allowable.

4. Reference Executive Summary by Data Lot. The range of measurements for this set is 0.001439" as an aggregate series and all measurements are well within the tolerance allowables of 0.3775"/0.3805". Individual Hole Computer Printout discloses the range of measurements to be very good. Only four (4) holes slightly exceeded 0.001" total ranges and are displayed as follows in increasing order of magnitude:

Hole #	Range
24	0.001017"
27	0.001089"
28	0.001155"
25	0.001319"

All other holes of the set were less than 0.001" in total range of measurements.

The reader is reminded of the fact that the Profile Displays on the Computer Printout when exhibited by the figure "0", is representative of 0.0001" per "0"; thus, it follows, we are dealing in very minute deviations in this series of holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #28 and discloses a value of 0.001086" at plane level #2 on the 0°-90° axes. Enlargement at the entrance plane of measurements most probably is the result of "drill grab" at its start into the hole. The magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality. It disappears at its next plane of measurements.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90°) to the longitudinal axis of the holes with regard to the drilled/reamed wing root forging structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: This feature along with its representative hole examples is addressed in the narrative per item III.A.3.a.

G. Hole Texture: Rifling, Scratches Chatter marks. This set of holes exhibited a very good interior wall texture. There were no perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This structure, drilled and reamed through one (1) solid flange was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 21 *

HOLE SIZE: 0.625"/0.6260"

I. <u>OVERVIEW:</u>

A. This set of survey holes features Quackenbush drilling and final reaming of Center Wing Lower Surface Main Landing Gear Trunion mounting holes. The main landing gear trunion perse' is not included in the measurements taken for these holes. The Quackenbush mounting/positioning drill plate is coordinated to the trunion fitting and provides for basic hole locations, perpendicularity and interchangeability reliability.

The hardware in the assembly is a mix of steel and aluminum at approximately 1.2" thich at the forward hole. The outer member is steel (approx. 0.31") thick, followed by the aluminum skin (approx. 0.25") and rib (approx. 0.56").

The aft hole is a different configuration at approximately 1.5" thick. The outer member is steel (approx. 0.31"), followed by the skin and stringer #19 (each approx. 0.25") rib (0.68").

The hardware is one piece, the wing splice fitting at approximately 1.75" thick.

Perpendicularity of the mounting holes to the assembly is a function of tooling coordinated to the machining of the trunion fitting, W.S. 90.00 rib and W.S. 110 splice fitting machining. The subject hole is sized by Engineering at 0.6250"/0.6260".

* DRILL METHOD CODING: Q-2 = Quackenbush - Air Power Reamer, Mechanical

Quackenbush drilling, final reaming.

II. SUMMARY:

A. Reference "Executive Histogram by Data Lot." The data population for this set is fairly evenly distributed over the entire 0.001000" range of the Engineering tolerance. This characteristic results from the multiple set-ups to acquire the set and the minute bellmouth/barrelling resulting from the chip load and operator side-loading. Variations are extremely small and the overall quality of the specimens is geometrically very good.

Nineteen (19) holes were available in this structure for survey inspection. All of the holes except Hole #1, 8 and #12 of this set meet the established Engineering criterion. Reference "Executive Summary by Data Lot." This set discloses a measurement distribution whose arithmetical average is 0.625624" for the series of nineteen (19) holes. This value is very good since it resides at the mid vicinity of the tolerance range. The affect of deep reaming with traces of chip build up and minor barrelling is apparent in some holes of this set.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Quackenbush preliminary holes are being satisfactorily produced to specification tolerance.

2. Quackenbush air powered drill motor driving a piloted tip reamer produces very good final holes per 0.6250"/0.6260" tolerance criterion.

3. The affect of good tooling is evident in the shape and quality of these holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1508 data measurements were accrued from the nineteen (19) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.625624" which is very good for the set and is reflected in the quality of these very deep holes whose tolerance spread is only 0.0010" total.

Slight chip load build up in the process of reaming exceptionally deep holes results in some minute tapering (bellmouthing) and bulging (barrelling) which are the only geometrical features departing from ideal cylindricity in the holes.

All of the specimens conform to the tolerance criterion established by Engineering except Holes #1, 8 and #12.

1. Hole #12. Reference Individual Hole Computer Printout. This hole exhibits the largest series of measurements in this set. The maximum value was recorded at 0.628379" on the 0° axis of measurements and at plane level #24, (the exit plane of the hole). Reference to the Computer Profile presentation reveals a side loaded feature in the hole along its 0° and 135° axes. This characteristic persists over the lower one half of the total hole depth and is a relatively smooth and tapered phenomenon, largest at the exit plane of the hole.

   Cause for the 0° - 135° adjacent axis enlargement is most probably the result of operator induced side loading via handling and/or leaning on the Quackenbush drill power head during its duty cycle in reaming.

2. Hole #1. Reference Individual Hole Computer Printout. Hole #1 is similar to Hole #12 by exhibiting oversize measurements along its 90° - 135° axes. The maximum recorded measurement is 0.627750" which occurs on the 90° axis at plane level 18, (1.2" down into the hole).

   The length of the oversize area is 0.3" long vertically along the 90° - 135° axes. Operator induced side loading during the Quackenbush reaming duty cycle is assessed the cause for this slight geometric flaw in Hole #1.

3. Hole #8. Reference Individual Hole Computer Printout. This hole exhibits an identical characteristic to Hole #1, and along identical 90° - 135° adjacent axes. The maximum recorded value for Hole #8 is 0.626983" which occurs on the 135° axis of measurements and at plane level #22, just prior to exiting the hole. The final one third of the total hole depth is affected by a side-load induced oversize feature.

   Cause for the overside bulge along the 90° - 135° axes on Hole #8 is identical to the preceding Holes #12 and #1. Handling of the Quackenbush unit during its duty cycle is prone to result in sideload ovality in the structure.

4. Reference Individual Hole Computer Printouts for holes identified Hole #4, 5, 6, 7, 9, 10, 13, 17 and #19.

   In the above series of holes the profiles established by generally ninety-six (96) measurements per hole via the 0°, 45°, 90° and 135° axes disclose their profiles to be nearly geometrically perfect.

The range of measurements for the above holes is less than 0.0003" as follows:

Hole #	Range	Hole #	Range
4	0.000276"	10	0.000129"
5	0.000221"	13	0.000233"
6	0.000259"	17	0.000276"
7	0.000276"	19	0.000197"
9	0.000224"		

The extremely slight departures from ideal cylindricity is assessed the result of very minor chip load build-up during the course of final reaming. The magnitude and progression is very minute and is not considered a departure from overall hole quality.

5. Reference Individual Hole Computer Printouts. Extending the limit criterion to 0.0005" incorporates <u>all</u> of the remaining holes of this set as follows:

Hole #	Range	Hole #	Range
2	0.000371"	15	0.000353"
3	0.000343"	16	0.000526"
11	0.000457"	18	0.000422"
14	0.000526"		

6. There are no gross outstanding geometric features detracting from the overall quality of these holes. The chip load enlargement is extremely minute and aside from the side-load ovality enlargement discussed at items III.A.1 thru III.A.3., this set is an extraordinary good series of holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #12 and discloses a value of 0.002922" on the 0^o - 90^o axes at plane #24. Ovality is a function of the operator induced side loading during the duty cycle of final reaming. Reference narrative at paragraph III.A.1.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (predominantly less than 0.0002"). Except for Holes #1, 8 and #12, all other holes of this set are well within the established Engineering criterion.

C. Perpendicularity: Reference Section I.A. of this report. Heavy custom tooling compensates for the angularity variation from the skin contour to the final machined surfaces of the main landing gear trunion fitting. These holes are normal to the trunion fitting and bearing surfaces of the mounting bolts.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent per profile analyses except as referenced per paragraph III.A.

F. Bellmouthing: Non-existent per profile analyses except per definition as related at paragraph III.A.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture.

The holes were inspected via Sight Pipe at 3X magnification. There were no rifling, chatter marks nor vertical scoring in this lot of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this lot exhibited a surface finish of approximately 63AA. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 22 *

HOLE SIZE 0.3745"/0.3755"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of a Longeron. The structure is aluminum approximately 1.000" thick at the surface to be drilled and reamed and the hole being inspected is sized at 0.3745"/0.3755" by Engineering.

II. SUMMARY:

A. Only three holes of this set of twenty-nine met the Engineering tolerance on all of the measurement points within the hole. Twenty-six (26) holes exceeded the Engineering tolerance in amounts varying from 0.0001"/0.0002" on Hole #18, to a maximum of 0.0013" oversize at Hole #26. All of the remaining oversize holes ranged between the extremes of Holes #18 and #26. Generally, a spread of 0.0001"/0.0006" covers these holes. Inspection was performed by "thru-hole air probe".

The computer data Statistical Printout for this series of holes provides a composite traceable to the following for the production of holes:

1. Custom fixture design for interface control/interchangeability reliability and Desoutter drill adaptation.

2. Desoutter drill/reaming method and accessories for production of the holes.

3. Planning is excellent for inspection traceability on holes.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical
Desoutter drill/reaming & accessories.

4. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

NOTE: The technician responsible for production of these holes was truly concerned over the fact that his job station showed a consistent oversize hole condition. He expressed a desire to pursue a cause/corrective action liaison with tooling/supervisory personnel to eliminate the problem.

B. A Desoutter manually operated rack feed drill was used for the drill and finish reaming operations on these holes. Characteristically the three holes which met the Engineering limits also showed a trend toward the high limit. Using the Hole Profile Data of the Statistical Printout, possible causes for the oversize condition in this set of holes may be laid to the following:

1. Spurs in the profile are suggestive of chip load and occur at various levels.

2. Irregularities in manual feed rate.

3. Wobble owing to the weight moment of the drill in handling during drill/ream operations.

4. Reamer condition (size and condition of the tool). Considering the care of drills/reamers at this facility and its system of use/return/recheck prior to reuse, Item #4 is rather remote.

III. CHARACTERISTICS:

A. Hole Size: All holes except Hole #21, #28 and #29 exceeded the allowable Engineering criterion of 0.3745"/0,3755". The individual sizes are provided in the Computer Data Printout. Measurements were taken at 36 locations within each hole.

III. A. (Continued)

With the exception of Hole #10 and Hole #26 which exhibited a maximum size of 0.0011" and 0.0013" respectively, the remainder of the set were grouped around an oversize value ranging between 0.0001" to 0.0006".

The following conditions are suggestive of the probable causes for the oversize end product:

1 - Tolerance of only ± 0.0005" on a long engagement hole.

2 - Manual feed control causing irregular loading on the reamer.

3 - Inadvertent wobble caused by Desoutter handling by the operator during drill/reaming.

B. Ovality: Maximum recorded ovality within the set was 0.000776" at hole #23. Individual holes within this set (36 measurements per hole) ranged to as low as 0.000078" at Hole #21.

The cause for the slight ovality spurs within this set of holes is considered the result of chip load since it generally occurs deep inside the hole and tapers when considering the four (4) plane level readings.

C. Perpendicularity: Characteristic is assured by custom fixturing. Part design has slight taper with regard to holes.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: Holes #11, #12 and #15 evidence a barrelling characteristic as indicated by the profile analyses.

F. Bellmouthing: Hole #25 contains a double bellmouth evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 23 *

HOLE SIZE 0.2500"/0.2540"

I. OVERVIEW:

A. This set of production holes features drilling of a structure, approximately 0.687" thick. This is an aluminum stack-up of three (3) laminates (-001 machined fitting, web and -003 machined fitting). The subject hole is sized by Engineering at 0.2500"/0.2540" for HiLok fastener installation, Type II, per STP 2006.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a pilot drilled -001 machined fitting to assure basic hole location. These holes were drilled on assembly by hand-held, air powered drill motor for all drilling operations. Reaming was not planned nor performed to obtain the final hole sizing. Several drilling operations were performed to arrive at the final hole size. Drill stalling was an infrequent occurrence on this series of holes, and most probably was a product of less material removal between the drill steps leading up to final sizing of the structure being drilled. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. These holes disclose a measurement distribution whose arithmetical average is 0.250414" for the set of twenty-nine (29) holes. Only four (4) of the holes of this series disclosed a size configuration in very minor conflict with the low limit (0.2500") criterion established by Engineering. These holes were of good quality but a trifle undersize.

* DRILL METHOD CODING: H-1 = Hand-held drill, No Reaming. Pilot drilled -001 machined fitting. Hand-held, air powered drill. No reaming.

II. B. (Continued)

The entire set of 1044 hole measurements, per disclosure on the Executive Summary Histogram for this set, are populated at the 0.250000"/0.251000" area of the Histogram. This close association to the low limit of the tolerance supports the suspicion that a 1/4" drill, sized at its acceptable low limit tolerance (0.2490"), per American Standard Twist Drill Tolerance, was used in the final drilling operation. The geometric features of this set of holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Hand-held, air powered drill method and accessories produces good basic holes. Accessory tooling was a drill block, secured by cleco clamping in a preceding hole to stabilize the tooling against "roll-over" during drilling. Drill block is similar to spacematic drill locating.

3. Reaming was not planned nor employed to obtain the final hole size.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: These are excellent holes. 1044 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set at 0.250414" is an ideal attribute considering the 0.2500"/0.2540" established Engineering Criterion.

III. A. (Continued)

This series of holes additionally is exceptionally good on "roundness". In several cases only 0.0001"/0.0002" separates the 36 measurements made in <u>each hole</u>.

a. A 1/4" drill sized at 0.2490" is suspected as the drill used for the final hole since all of the holes are clustered at 0.250" to 0.251" measurement distribution.

b. Holes #4, #21, #23 and #24 exhibit the undersize features.

1. Hole #4 Individual Profile discloses the 0^{o} and 45^{o} axes to be excessively side loaded with regard to the remaining 90^{o} and 135^{o} axes. Operator instability during drilling is suggestive of this characteristic inside the hole.

2. Hole #21 discloses only two (2) measurements undersize. These occur at Level #4 and #5 on the 90^{o} orientation axis. Both are discounted as particle contamination on the air-probe and not a hole defect condition.

3. Hole #23 is an ideal candidate in support of the 0.2490" drill size. Individual Hole Profile Printout discloses a tapered condition, largest at the base of the hole and progressively diminishing in diameter (4 to 5 plane levels) into the hole. Chip load

III. A. (Continued)

build-up is the most probable cause for the taper in Hole #23.

4. Hole #24 is insignificant on its undersize condition. Less than 0.0001" separates the entire series of thirty-six (36) measurements. This hole is excellent.

c. Holes #7, #8, #11, #13, #18, #24 and #26 are nearly perfect holes. Considering the overall depth of the hole at approximately 11/16", hand-drilling and minimal assist tooling, these holes are "testbook specimens."

d. The Individual Histograms disclose a normal Gausian Distribution signifying a harmonious marriage of process, tooling and operator personnel.

B. Ovality: Hole #4 revealed a maximum ovality within the set and was recorded at a magnitude of 0.001388", at level #5 on the 45°-135° axes. Ovality was induced by operator side loads as described in item III.A.b.1.

Ovality was not a cause for concern on this set of holes. Holes #7 and #24 recorded values as low as 0.000060" and 0.000052" for this feature. There are no ovality conditions in this set which exceed the Engineering Criterion.

C. Perpendicularity: The structure geometry would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation

III. C. (Continued)

and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Hole #4 Individual Profile reveals a very subtle barrelling feature which is the result of drill operator instability. The feature does not exceed the tolerance permitted by Engineering and there were no other barrelled holes within this set.

F. Bellmouthing: Evident in every minute and subtle amounts as indicated by Holes #1, #15, #23 and #25. Various other holes of this set exhibit the same condition at either their entrance or exit planes of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 24 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling of the Skin to Rib, Mid-Inboard Flap Assembly. The structure is an all aluminum stack whose thickness in the area to be surveyed is approximately 0.50". The subject hole is sized by Engineering at 0.2460"/0.2500" for installation of Flush Hi-Lok bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. All holes of this set are in complete compliance with all Engineering criterion. Measurement data was accumulated at sixteen (16) locations within each hole via "thru-hole" air probe. Quality of the holes will be discussed in detail in paragraph III. along with other geometric features of these holes.

B. Reference Executive Summary by Data Lot. This set discloses a Measurement distribution whose arithmetical average is 0.248114" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point of the Engineering tolerance range.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces good holes at assembly without follow-on reaming.

* DRILL METHOD CODING: S-1 = Spacematic - One Shot-No Reaming Spacematic, air powered drill and accessory tooling.

II. C. (Continued)

3. Reaming was not a requirement in the production of these holes.

4. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 464 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.248114", is an ideal characteristic in regard to the Engineering criterion of 0.2460"/0.2500". This is a very good series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Seven (7) holes are nearly perfect with their total spread of sixteen (16) measurements per hole having recorded the following range:

Hole #	Range	Comment
1	0.000422"	See Note*
3	0.000335"	
5	0.000302"	
6	0.000302"	
7	0.000391"	
11	0.000460"	
29	0.000466"	

III. A. (Continued)

Note* Generally a very subtle ovality at the start plane of drilling or at the exit plane is the feature accounting for otherwise perfectly drilled holes.

2. The remainder of the holes comprising the series comply with all Engineering tolerance criterion on size and shape. Reference Executive Summary Histogram. The data population discloses spikes, prior to and after the 0.248000" reference, rather than a Normal Gausian Distribution. Cause for the data distribution spread is explained as follows in item III. A. 3.:

3. Reference Individual Hole Computer Printout. Two (2) characteristics detract from otherwise excellent holes and are identified as follows:

   a. Bellmouth and/or taper at the entrance vicinity of the holes. Holes #2, #4, #9, #16, #17 and #24 are representative examples.

   b. Bellmouth and/or taper at the exit vicinity of the holes. Holes #22, #23, #25, #26 and #27 are representative examples.

   The cause for the taper featured at the start plane of the holes is suggestive of minor drill "seeking" of the tip on drill entry since the oval feature is <u>rather uniform</u> at all axes of measurement.

III. A. (Continued)

The cause for the taper and/or bell-mouth at the exit vicinity of the holes is suspected as drill heat generated by the absence of coolant. The exit areas also are uniform on axis distribution of the taper feature suggesting chip load build-up prior to breakout.

Reference Executive Summary by Data Lot. The range of measurements for this set is 0.002155" as an aggregate series and all measurements are within the tolerance allowables of 0.2460"/0.25500". Individual Hole Computer Printout discloses the range of measurements to be very good. Only four (4) holes slightly exceeded 0.001" total ranges and are displayed as follows in increasing order of magnitude:

Hole #	Range
25	0.001017"
14	0.001038"
21	0.001276"
19	0.001664"

All other holes of the set were less than 0.001" in total range of measurements.

The reader is reminded of the fact that the Profile Displays on the Computer Printout when exhibited by the figure "0", is representative of 0.0001" per "0"; thus, it follows, we are dealing in very minute deviations in this series of holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #19 and discloses a value of 0.001054" at plane level #1

III. B. (Continued)

on the 0^{o}-90^{o} axes. Enlargement at the entrance plane of measurements most probably is the result of "drill grab" at its start into the hole. The magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality and disappears at its next plane of measurements.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Nonexistent as evidenced by profile analyses.

F. Bellmouthing: Evident in minute and subtle amounts as indicated by holes identified per item III. A. 3. a. and III. A. 3. b. Various other holes of this set exhibit the same condition at their entrance and exit planes; however, none of the conditions exceed the allowable Engineering tolerance.

III. (Continued)

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and rib were deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 25 *

HOLE SIZE: 0.3080"/0.3130"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Center Wing Outboard Wing Fitting to Skin Panel Assembly. The structure is an aluminum stack-up of tapered thickness. The area subject to survey inspection is approximately 0.60" thick. The subject hole is sized by Engineering at 0.3080"/0.3130" for HiLok bolt installation.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy drill plate and fixturing to facilitate Spacematic, air driven drill power head. Freon spray-mist coolant was used from a gravity fed, hand-held delivery wand. Holes were drilled by "one-shot" spacematic method to their final size configuration and no reaming was planned nor employed. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.310902" for the set of twenty-nine (29) holes. This value is a very desirable feature since it resides at the mid-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

* DRILL METHOD CODING: S-1 = Spacematic - One Shot No Reaming
Spacematic, air powered drill & accessory tooling.

II. C. (Continued)

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces good final sized holes at assembly on a "one-shot" operation.

3. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 928 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set 0.310902", is an ideal characteristic in regard to the Engineering criterion of 0.3080"/0.3130". This is an excellent series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Six (6) holes are nearly perfect with their total spread of thirty-two (32) measurements per hole having recorded the following range:

Hole #	Range	Comment
4	0.000405"	See Note*
9	0.000498"	
14	0.000474"	
17	0.000500"	
21	0.000414"	
28	0.000491"	

III. A. (Continued)

Note* Generally a very subtle ovality at the start plane is the feature accounting for otherwise perfectly drilled holes.

2. Six (6) holes exhibit bellmouth and/or taper which is very minute as it approaches the exit plane of the hole. A rather uniform straight taper is featured in these holes, increasing in diameter as depth in the hole approaches the exit plane. The subject holes and measurement ranges are:

Hole #	Range	Comment
3	0.000759"	See Note **
18	0.000948"	
20	0.001345"	
22	0.001052"	
23	0.001000"	
29	0.001317"	

Note** The magnitude of the bell-mouth and/or taper in the aforenoted holes at worst case is only slightly over 0.001". The computer print-out discloses the profile phenomenon. This grouping of holes is purposefully being discussed adjacent to the series in item III.A.1 to apprize the reader of the ability of the computer to construct a pictorial replica of the hole using very minute measurement differences.

III. A. (Continued)

The general condition of this series of holes suggests possible freon spray-mist coolant starvation during the duty cycle of the drilling which induces drill heating and chip loading. The consequence is hole enlargement to a very small magnitude which does not exceed the Engineering tolerance criterion.

3. Very minor drill "seeking" is apparent at the drill entry vicinity of several holes resulting in a double bellmouth taper when coupled with the coolant starvation condition described above in item III.A. 2. Holes #1, #5, #19 and #22 provide examples of the above features in the holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #5 and discloses a value of 0.001164" at plane level #1 on the 0°-90° axes. Slight enlargement at the 0°-90° axes was most probably induced by drill "seeking" at the start of its duty cycle. The ovality is slight and <u>does not</u> exceed the Engineering tolerance criterion. Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to

III. C. (Continued)

the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Hole #3, #18, #20, #22, #23 and #29 per item III. A. 2. Various other holes of this set exhibit the same condition at their entrance plane of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and fitting was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 26 *

HOLE SIZE 0.185"/0.188"

I. OVERVIEW:

A. This set of production holes feature freehand drilling of the Beam Assembly. The structure is an aluminum stack-up approximately .300" thick. The subject hole is sized by Engineering at 0.185"/0.188".

Hole survey measurements were obtained using a Diatest Split-Ball Gage that incorporates an Alina linear displacement measurement transducer and is coupled to an Automated Computer System for data storage and recovery.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated pre-drilled fuselage stiffener basic hole locations. A hand-held, air powered, drill motor driving a double-margin piloted tip drill was employed to obtain a "one-shot" final sized fastener hole.

Reaming was not required, nor planned, in order to achieve final hole size integrity and finish texture.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.187652", not a desirable condition since the low and high limit criterion is 0.185"/0.188" respectively as established per Engineering. Eight (8) holes reveal ou of tolerance measurements. These oversize holes along with other specific characteristics relating to these holes are discussed in detail at paragraph III.

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of satisfactory holes:

* DRILL METHOD CODING: H-1 = Hand-held Drill, No Reaming. Hand-held, air powered drill driving a double margin piloted tip drill. No reaming.

II. C. (Continued)

1. Custom designed assembly fixturing ensures structure alignment and positioning reliability.

2. Hand-held, air powered drill motor and piloted tip drill are adequate to the production of finished holes. Reaming not a requirement.

3. Detail planning is adequate for the definition of the operational steps required to produce the part and hole inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary by Data Lot". 232 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.187652".

b. The Executive Summary Histogram reveals the data distribution to be <u>totally</u> populated about the 0.187000" to 0.188000" zone and <u>beyond</u>, into an out of tolerance situation. This trend is <u>not out of the ordinary</u> considering the <u>absence</u> of guide tooling such as hand-held drill bushing and the known inherent instability of the drill technicians where there is an absence of assist tooling. The relative thinness of the structure being drilled also contributes to the probability of producing oval and enlarged holes when free-hand drilling.

c. The eight (8) oversize holes are distributed as follows:

Holes #1, #2 and #29 disclose their oversize feature at the start plane of drilling.

III. A. c. (Continued)

Hole #1 maximum oversize recorded at 0.000250" at Level #1 on its 45° axis.

Hole #2 maximum oversize recorded at 0.000310" at Level #1 on its 0° and 45° axis.

Hole #29 maximum oversize recorded at 0.000353" at Level #1 on its 45° and 90° axis.

Hole #10 and #16, less significant, disclosed their maximum oversize conditions to be 0.000172" and 0.000181" respectively. Both occurred at their 0° axes and at the exit plane (Level #2) of the drilling.

Freehand drilling and relative thinness of the structure being drilled is the suggested cause of the slight oversize conditions for these holes. Historically, depth accumulation on drilling improves the condition of the holes on size, roundness and other geometric features where freehand or minimal guide tooling is used.

Holes #6, #7 and #8 exhibit full depth oversize conditions. Cause and correction are the same as the previous disclosure.

B. Ovality: Hole #7 exhibited the greatest ovality of the set at 0.000474". Ovality was not a problem for this set since all of the holes were within the Engineering tolerance. Insufficient depth on this lot of holes prevented the accumulation of significant data to establish true geometric features in the holes.

III. (Continued)

C. Perpendicularity: Insufficient hole depth precludes accurate measurement. Fastener head gap was employed to verify perpendicularity acceptance.

D. Straightness: Straightness is within Engineering design tolerance via gage acceptance by the holes and fasteners.

E. Barrelling: Insufficient data elements owing to shallow depth of hole to obtain meaningful data for analysis.

F. Bellmouthing: Generally present by virtue of free-hand drilling technique. Item III. A provides narrative disclosure on over-size holes which in general are "bellmouthed". Greater hole depth would have disclosed more positive feature trend.

G. Hole Texture: Rifling, Scratches, Chatter marks. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: Assembly was disassembled and deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD MS

RANKING NUMBER 27 *

HOLE SIZE: 0.1870"/0.1885"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of a Wing Front Spar Assembly. The assembly is approximately 0.30" thick in the area being surveyed and the subject holes are sized per planning at 0.1870"/0.1885" for installation of 3/16" HiLok Fasteners.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey. The method of production featured a track mounted air powered drill for preliminary holes. Location was controlled via drill plate with integral fixed drill bushings. Reaming of the holes follows to achieve final Engineering size. Measurement data was accumulated at sixteen (16) locations within each hole via "thru-hole" air probe.

B. Reference "Executive Summary by Data Lot." This set discloses a measurement distribution whose arithmetical average is 0.188355" for the set of twenty-nine (29) holes. The aforenoted average, very close to the extreme high limit of the Engineering tolerance, supports the conclusion that a process review is apropos to reverse the trend toward an out of tolerance processing operation.

An inherent bellmouth and/or taper is apparent throughout these holes resulting in a chronic, slightly oversize condition in most of the holes of this series.

Specific discussion on the geometric characteristics of the holes, including the exception above, are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability.

2. A track mounted, air driven power unit produces preliminary holes prior to reaming to their final Engineering size.

* DRILL METHOD CODING: MS = Miscellaneous Systems - Track Mounted Drill
Track mounted, air driven power unit w/air powered drill driving a piloted reamer.

3. Reaming is accomplished via the same air powered drill driving a piloted reamer to acquired final hole size at 0.1870"/0.1885".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 464 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.188355", is a direct result of the inherent bellmouth feature exiting on the holes.

1. Reference Individual Hole Computer Printouts. The bellmouth feature exists at the exit plane of the holes in regard to the direction of drilling and reaming. The magnitude of taper is slight, exhibiting a maximum of 0.0008" at Holes #14 and #15. The remainder of holes are less on the taper feature.
Cause of the taper is suggestive of chip load induced as a function of the bushings bearing against the hardware being drilled. Chip clog build-up generally is associated with such tooling configuration and results in chip load enlargement of the holes at their exit plane vicinities.

2. Reference Holes #14 and #15 Computer Printouts. Although these specimens exhibit the greatest taper feature at 0.0008", they remain acceptable from the standpoint of quality and Engineering tolerance criterion. Hole #14 discloses a very insignificant spur at 0.188543" at its 90° axis and 0.188655" at the 135° axis. Both occur at the exit plane of the hole and are the result of irregular break-out load on reaming. The location of these spikes and their magnitudes are not considered an impact on hole quality by this analysis.

3. Reference Individual Hole Computer Printouts. Six (6) holes, identified Holes #7,#8,#10,#23,#25 and #27 are oversize.
All sixteen (16) measurements of these holes feature values in excess of the Engineering high limit 0.188500". All of these specimens feature the slight taper toward their exit plane of measurements in addition to their basic oversize condition. Generally, 0.0005" defines the taper existing in these holes.
Cause for the oversize and taper is attributed to chip load build-up due to insufficient clearance between the drill guide bushings and the structure being drilled/reamed.

3. Reaming is accomplished via the same air powered drill driving a piloted reamer to acquired final hole size at 0.1870"/0.1885".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 464 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.188355", is a direct result of the inherent bellmouth feature exiting on the holes.

1. Reference Individual Hole Computer Printouts. The bellmouth feature exists at the exit plane of the holes in regard to the direction of drilling and reaming. The magnitude of taper is slight, exhibiting a maximum of 0.0008" at Holes #14 and #15. The remainder of holes are less on the taper feature.
Cause of the taper is suggestive of chip load induced as a function of the bushings bearing against the hardware being drilled. Chip clog build-up generally is associated with such tooling configuration and results in chip load enlargement of the holes at their exit plane vicinities.

2. Reference Holes #14 and #15 Computer Printouts. Although these specimens exhibit the greatest taper feature at 0.0008", they remain acceptable from the standpoint of quality and Engineering tolerance criterion. Hole #14 discloses a very insignificant spur at 0.188543" at its 90° axis and 0.188655" at the 135° axis. Both occur at the exit plane of the hole and are the result of irregular break-out load on reaming. The location of these spikes and their magnitudes are not considered an impact on hole quality by this analysis.

3. Reference Individual Hole Computer Printouts. Six (6) holes, identified Holes #7,#8,#10,#23,#25 and #27 are oversize.
All sixteen (16) measurements of these holes feature values in excess of the Engineering high limit 0.188500". All of these specimens feature the slight taper toward their exit plane of measurements in addition to their basic oversize condition. Generally, 0.0005" defines the taper existing in these holes.
Cause for the oversize and taper is attributed to chip load build-up due to insufficient clearance between the drill guide bushings and the structure being drilled/reamed.

4. Reference Individual Hole Computer Printouts. Several other holes of this set exhibit oversize dimensions. They are identified Hole #1,#6,#11,#13,#16,#17,#20, #28 and #29. These holes are similar in features to the previously discussed holes in that the feature resulting in their oversize conditions is taper and/or bellmouth occurring at their exit plane vicinities. Cause has been previously defined and associated with chip load build-up.

5. Reference Executive Summary Histogram. The data profile for this set populates the entire tolerance/oversize zones and features various spikes. The data is indicative of the hole variations experienced via the bellmouth feature discussed in the aforementioned text.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #7 and discloses a value of 0.000776" at plane level #1 on the 45°-135° axes. Hole #7 Individual Profile discloses a lead-in ovality enlargement at its entrance plane. The condition is suggestive of chatter center seeking at start of reaming resulting in slight oval enlargement of the hole.
Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be very good on ovality measurements. None of the holes of this series exceeded the Engineering tolerance for ovality.

C. Perpendicularity: The Spar Assembly geometry would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None-existent as evidenced by profile analyses.

F. Bellmouthing: Evident throughout this set in varying amounts as indicated per item III.A.1. The holes of this group exhibit the bellmouth/taper condition at their exit plane of drilling and reaming. Cause has been related to chip load build-up.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of web and spar cap, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this exhibited a surface finish of "100AA" or better. Optical surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 28 *

HOLE SIZE: 0.625"/0.630"

I. OVERVIEW:

A. This set of production holes features Quackenbush drilling and reaming of a Fuselage.

The structure is all aluminum approximately 0.87" thick and is the fuselage wing root attach point area. The subject hole is sized by Engineering at 0.625"/0.630".

II. SUMMARY:

A. Twelve (12) holes, representative of three (3) ship sets, were available in this structure for survey inspection. The method of production was Quackenbush drilling and reaming. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.628054" for the set of twelve (12) holes. This value is a very good feature since it resides at the mid-vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces good preliminary holes at assembly.

* DRILL METHOD CODING: Q-2 = Quackenbush - Air Power Reamer Mechanical

Quackenbush, air powered drill and accessory tooling

II. C. (Continued)

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. CHARACTERISTICS:

A. Hole Size: 576 data entries were accrued for the series of twelve (12) holes. The arithmetical average for the set is 0.628054", well below the 0.630" high limit per established Engineering Criterion. This is a very good series of holes on size and shape features. Considering the hole depth at nearly one inch, excellent profile data was obtained on the computer tapes. The most predominant geometric feature apparent via data analysis for this set is slight barrelling in several of the holes. The feature exists but is well within the tolerance per Engineering Criterion.

1. Basic hole size was extremely consistent as evidenced by the range measurements of the set. Range also is the predominant factor in determining hole shape for this set. A series of measurements taken at forty-eight (48) locations within each hole yields the following:

III. A. (Continued)

Hole #	Range
1	0.000638"
2	0.000733"
3	0.000734"
4	0.000466"
5	0.000819"
6	0.000784"
7	0.000405"
8	0.000491"
9	0.000741"
10	0.000759"
11	0.000621"
12	0.000793"

In the above series of holes, Holes #1 through #4 equal one ship set. Hole #5 through #8 and #9 through #12 are the final two (2) ship sets of holes.

2. Reference item III. A. 1 and Individual Computer Printouts. Four (4) holes, identified Hole #2, #3, #6 and #10 exhibit an extremely slight barrelling effect on their Individual Profile Printouts. In all cases the cause is subtle chip enlargement as depth in the hole is acquired. The growth is relatively uniform and as clearance is achieved, a decline of chip load is apparent which is also relatively uniform. Although chip load-up is the prime suspect for the barrelling feature, coolant starvation with accompanying drill/reamer heat-up may also be a contributor to the slight enlargement feature.

III. A. (Continued)

3. Reference Individual Computer Print-outs. Holes #4, #7 and #8 are nearly perfect specimens with only occasional chip scars disrupting the individual hole profiles.

4. Reference Individual Hole Histograms. All hole Individual Histograms disclose a Normal Gausian Distribution on data. Each hole exhibits an excellent data population. This data is indicative of tools, process and personnel operating in harmony.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #12 and recorded at 0.000526" at Level #11 on the $0^{o}-90^{o}$ axis. This value is negligible and does not cause quality degradation of the hole. Ovality was a function of chip spurs inside the hole that were not perceptible to the naked eye.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90^{o}) to the longitudinal axis of the holes and Butt Line plane milled on the structure at assembly.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: This characteristic has been addressed per narrative at item III. A. 2. The

III. E. (Continued)

feature is extremely slight and does not violate the tolerance criterion established per Engineering.

F. Bellmouthing: Hole #1 and #9 exhibit a very negligible taper per Individual Hole Computer Profiles. Both are very minute and do not exceed the Engineering allowable criterion.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish between "63 AA" to "100 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-2

RANKING NUMBER 29 *

HOLE SIZE: 0.3090"/0.3110"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of a Wing Splice Installation. The structure is the left hand wing bottom panel. The area for hole survey is the outboard row of 5/16" fasteners identified WZ 10 (HL19PB; HiLok Flush Bolts), located 0.68" inboard from the toe of the main splice forging. The assembly is approximately 0.60" thick in the area being surveyed and the subject holes are sized per planning at 0.3090"/0.3110".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey. The method of production featured preliminary Spacematic drilling of the structure followed by hand reaming of the holes to achieve final Engineering size. Measurement data was accumulated at twenty-eight (28) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.309943" for the set of twenty-nine (29) holes. Normally the aforenoted average would be considered a desirable feature since it resides at the mid-point of the Engineering tolerance range; however, there is an adverse inherent "bellmouth" characteristic throughout this series of holes.

Despite the bellmouth feature, all of the holes of this set, except Hole #8, meet all Engineering criterion.

Specific discussion on the geometric characteristics of the holes, including the exception above, are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

* DRILL METHOD CODING: S-2 = Spacematic - Hand-held reaming.

Spacematic, air driven power unit w/hand reaming.

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Spacematic, air driven power unit produces preliminary holes prior to hand reaming to their final Engineering size.

3. Reaming is accomplished via hand-held air powered drill motor driving a piloted reamer to acquired final hole size at 0.3090"/0.3110".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 812 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.309943", is deceptive in the face of an inherent bellmouth feature exiting on the holes.

1. Reference Individual Hole Computer Printouts. The bellmouth feature exists at the entrance plane of the holes which is the outer surface of the wing in regard to the direction of drilling. The magnitude of taper varies from 0.002" at Hole #8 down to basically 0.0003" at Hole #3. The condition in itself does not exceed the Engineering tolerance (except for Hole #8), but it does illustrate via the Computer Profile Printout that all axes are affected by taper and diminish at a relatively consistent rate as depth in the hole is achieved.

   The condition is suggestive of chatter (center-seeking) of the reamer pilot since all axes are equally affected on magnitude.

2. Reference Hole #8 Computer Printout. This hole discloses an oversize condition at the first plane level of measurements. The condition achieves an in-tolerance posture at the second plane of measurement. Owing to the shallowness and magnitude existing at only the entrance plane of Hole #8, the condition is not considered a detriment to hole quality per this analysis.

   Reference note #1 on page 4.

3. Reference Holes #3, #13 and #24 Computer Printouts. Each of these holes exhibit an insignificant out-of-tolerance spike as follows:

Hole #	Spike Magnitude	Axis Affected
3	0.311064"	0°
3	0.311090"	45°
13	0.311121"	135°
24	0.311164"	135°

Center seeking at the start of reaming resulted in the noted data spikes. Their magnitude is not considered a detriment to hole quality in this analysis.
Reference note #1 on page 4.

4. Reference Executive Summary Histogram. The data profile for this set populates the entire tolerance zone and features various spikes. The data is indicative of the hole variations experienced via the bellmouth feature discussed in the aforementioned text. Additionally, there is an inherent instability associated with hand-held drill/reaming operations when assist tooling is not employed to help control alignment.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #26 and discloses a value of 0.001195" at plane level #2 on the 45°-135° axes. Enlargement ovality at this plane of measurements results from side loads induced via operator instability during reaming resulting in enlargement along the 90° and 135° axes. The magnitude does not exceed the Engineering tolerance criterion and is not a detracting feature for hole quality.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Absence of an appropriate plug to accommodate this hole size would not permit inspection via the Azimuth/Angle Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The longitudinal axis of the holes are normal (90°) to the skin outer surface and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None-existent as evidenced by profile analyses.

F. Bellmouthing: Evident throughout this set in varying amounts as indicated per item III.A.1. The holes of this group exhibit the bellmouth/taper condition at their entrance plane of drilling and reaming. Cause has been related to "center-seeking" resulting from hand reaming instability.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There was only very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel, shim and splice forging, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

<u>NOTE #1</u>: On this structure the planning document controlling the build via fabrication/inspection instructions specifies the 5/16" HiLok Fastener hole size to be 0.3090"/0.3110".

The Engineering drawing, 160D612110, sheet #1, specifies Installation of Flush Fasteners to be controlled per SP664.

SP664; Table II "Close Tolerance HiShear Fasteners" specifies the finished hole size for 5/16" fastener as 0.3105"/0.3125".

The analysis of this set of holes is based on the 0.3090"/0.3110" tolerance criterion.

DRILL METHOD H-2

RANKING NUMBER 30 *

HOLE SIZE: 0.1885"/0.1910"

I. OVERVIEW:

A. This lot of production holes feature drilling and reaming of the Carry Thru, Front Spar Assembly. The structure is an aluminum stack-up approximately .500" thick. The subject hole is sized by Engineering at 0.1885"/0.1910".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized a custom built assembly fixture to assure hole location. Holes were drilled by air powered hand-held drill and fixture lock-on guide bushing. Reaming was accomplished in like fashion with hand-held drill motor and a Cobalt step reamer sized at 0.1890". Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose Arithmetical Average is 0.189445" for the set of twenty-nine (29) holes. The holes of this series were of excellent quality.

The Executive Summary Histogram reveals the data distribution characteristic of a Normal Gausian Curve indicating that tooling, processes and personnel in harmonious control. All holes of this set were well within the Engineering established tolerance criterion.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom fixturing ensures interchangeability and location reliability.

2. Hand-held air powered drill and fixture lock-on guide bushing produce good preliminary holes.

3. Hand-held air powered drill motor with fixture coupled lock-on reamer guide bushing and Cobalt step reamer sized at 0.1890" produced excellent final reamed holes.

4. Detail planning is adequate for the definition of the operational steps required to produce the part and hole inspection requirements.

* DRILL METHOD CODING: H-2 = Hand-held Drill and Reamer
Hand-held air driven drill, using a Cobalt step reamer.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary" for this set. 696 measurements were recorded for this series of twenty-nine (29) holes. The average reading 0.189445" is excellent since it crowds the low range of the Engineering tolerance.

b. Reference "Executive Summary Histogram by Data Lot." The population of the data elements form a Normal Gausian Curve about the low limit of the tolerance revealing good control of tooling, process and personnel. Individual Histogram profiles for each hole support this conclusion.

c. Hole #18 disclosed one plane of measurements beyond the Engineering tolerance. It occurred Level #5 (Ref. Individual Computer Printout Hole Profile) and is suggestive of "chip gouge" resulting from the start of a new material thickness. The measurement plane immediately above this "scar" is the interface between two (2) members of the hardware stack. It was <u>discounted</u> for concern owing to the flat angle of the "scar" and the fact that it disappeared at the following plane of measurements toward the exit of the hole. 0.192164", the highest reading in this set occurs in the subject "scar" area.

d. Hole #15 as in "c" above revealed one plane of measurements beyond the Engineering tolerance. It occurred at Level #4 (Ref. Individual Computer Printout Hole Profile) <u>which is an interface</u>. The air probe sensed the interface faying surface gap and is therefore <u>discounted</u> as cause for concern.

e. Holes #1, #23 and #24 have a common characteristic of oversize which occurred at the "<u>start in plane</u>" of the drill/reamer and was discounted for concern since it disappeared at the following plane of measurements. A generous deburring chamfer at the edge of these holes resulted in the single plane of oversize dimensions.

B. Ovality:

Hole #23 exhibited the greatest ovality of the set with a reading of 0.001233" at the 0°-90° axes. Reference Item III. A. e above. As previously stated, this phenomenon occurred at the entrance plane of the hole and disappeared at the next

deeper level. Ovality ranged at low as 0.000043"/ 0.000078" at Hole #27. Generally ovality ranged less than 0.0005" in this series of holes.

C. Perpendicularity: All Holes within this set were normal to the longitudinal axis of the hole with regard to the structure station plane face. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None Evident as indicated by the profile analyses.

F. Bellmouthing: General tendency toward "bellmouthing" and or "taper" as evidenced by profile analyses but within the allowable Engineering tolerance criterion.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through a stacked arrangement of fuselage station frames, doubler and fitting were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 31 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Wing Lower Surface Longeron. The structure is a stack-up of steel longeron, aluminum skin panel and aluminum rib. The steel longeron is tapered in thickness. It varies from approximately 1/4" thick at front spar to 1/2" at the center spar, then returns to approximately 1/4" at the rear spar. The subject hole is sized by Engineering at 0.2460"/0.2500" for HiLok bolt installation.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy drill plate, pinned and clamped onto the wing structure to facilitate locking on the Quackenbush, air driven drill power head. Freon spray-mist coolant was used from a gravity fed, hand-held delivery wand. Holes were drilled by Quackenbush to a preliminary size of 15/64" and followed by hand-held, air driven drill motor, using a 3/8" length piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.248549" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of holes are discussed at paragraph III.

* DRILL METHOD CODING: Q-1 = Quackenbush - Hand-held Air Power Reamer

Quackenbush, air powered drill and accessory tooling.

II. (Continued)

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces good preliminary holes at assembly to 15/64" size.

3. Hand-held, air powered drill, driving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 1160 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.248549", well below the 0.2500" high limit per established Engineering Criterion. This is an excellent series of holes on size. Reference Computer Individual Hole Printout discloses the following:

1. Eight (8) holes are nearly perfect with the total spread of forty (40) measurements per hole having recorded the following range:

Hole #	Range	Comment
3	0.000405"	See Note*
5	0.000371"	
8	0.000509"	
9	0.000388"	
10	0.000405"	
12	0.000466"	
22	0.000345"	
29	0.000414"	

III. A. (Continued)

<u>Note*</u> Several holes, #5, #9, #10 and #12 reveal slight enlargement of the aluminum structure following the outer steel longeron. Steel chip impingement and/or slight operator instability during reaming are suggested cause for the enlargement.

2. Five (5) holes exhibit bellmouth and/or taper which is extremely minute at the entrance of the hole and progressing into the substrate materials as follows:

Hole #	Range	Comment
1	0.000638"	See Note**
4	0.001017"	
18	0.000836"	
25	0.000473"	
27	0.000578"	

<u>Note **</u> Several holes during the drilling/reaming process were observed being processed dry, without Freon Spray-mist coolant. The geometry of the profile of these holes typically suggest possible drill heat/reamer heat-up resulting in a larger hole in size and vertical profile.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #14 and recorded at 0.000586" at Level #5 on the 0^{o}-90^{o} axes. This value is <u>void</u>. An error in data reduction was committed. A faying surface interface was overlooked at Level #5 thus resulting in an erroneous computer printout.

III. B. (Continued)

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspection. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: Hole #28, Individual Profile, reveals a very subtle barrelling feature. Dry drilling is suspected as the cause for the geometric configuration of this hole. The feature is insignificant and does not exceed the tolerance allowable.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Holes #1, #4, #18, #25 and #27. Various other holes of this set exhibit the same condition at their entrance plane of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

III. (Continued)

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-3

RANKING NUMBER 32 *

HOLE SIZE 0.2450"/0.2480"

I. OVERVIEW:

A. This set of production holes features Quackenbush drilling of the Beam Frame Splice. The structure is a three (3) laminate stack of aluminum approximately .500" thick. The top splice plate and main beam faying surfaces are tapered to one another. On assembly lay-up the tapers are "nested" so that they present a constant cross-sectional thickness to the left and right of the "I" beam splice centerline. The inner channel is a constant, parallel thickness. The holes are sized at 0.2450"/0.2480" by Engineering.

Hole survey measurements were obtained using a Diatest Split-Ball Gage that incorporates an Alina linear displacement measurement transducer and is coupled to an Automated Computer System for data storage and recovery. Interpolation on data was performed where obvious measurement data reflected the probe to be sensing a faying surface gap created as a result of insufficient cleco clamp-up pressures on the structure.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production employed air powered Quackenbush drill for a "one shot" finalized hole. Interference encountered at assembly necessitated a freehand reaming operation to facilitate fastener installation on the structure under survey.

B. Reference to the "Executive Summary by Data Lot" discloses the arithmetical average for hole size to be 0.246802", an excellent feature since the low and high limit criterion is 0.2450"/0.2480" respectively as established by Engineering. All twenty-nine (29) holes of this set meet the Engineering criterion. Details concerning size and other geometric features of this series of holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed major fixturing assures structure alignment and positioning reliability.

* DRILL METHOD CODING: Q-3 = Quackenbush - One Shot Quackenbush - "one-shot" - freehand reaming.

2. Clamp on drill plate adapted to the Quackenbush air powered drill is adequate for the production of good quality, "one-shot", final sized holes. Occasionally, hand-reaming is necessary owing to fastener installation interference.

NOTE: Hand reaming was accomplished on this series of holes without accessory assist tooling.

3. Planning is adequate to direct manufacturing and inspection operational requirements.

4. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. CHARACTERISTICS:

A. Hole Size: a. Reference "Executive Summary by Dat Lot". 464 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.246802" and hole surface finish texture was "100 AA" or better, which is an added attribute contributing to the production of a good series of holes.

b. Reference to Individual Hole Computer Printout discloses the cluster of measurements from highest reading to lowest, per hole, to be less than 0.0010". Five (5) holes, identified #2, #4, #5, #13 and #15 were exceptions, which slightly exceeded the 0.0010" but still remained well within the Engineering tolerance spread.

B. Ovality: Hole #14 recorded the greatest ovality at 0.001026" at its 45° - 135° axes, Level #3. Hole ovality for this entire series was considered insignificant since the entire set of holes met the Engineering tolerance range and are less than the 0.0010" reported at Hole #14.

C. Perpendicularity: The holes of this set were by design too small to accept the Angle/Azimuth Gaging Device plug to determine perpendicularity via this means. Fasteners installed in several holes were inspected for perpendicularity via head to structure gap check at 3X magnification. The holes were perpendicular to the splice.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Occasionally evident in the minutest amount as evidenced by holes such as Hole #2, drill/reamer entrance plane to the hole and Hole #13, same as above.

Hole #13 exhibits a double bellmouth condition most probably the result of operator instability on the free-hand reaming operation that was performed on several holes. Bellmouthing, where it occurs in this set is extremely slight.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited very good interior wall texture. There was only an occasional very shallow angle rifling, generally in the vicinity of the laminate interfaces. Inspection was performed via Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through approximately 0.500" of stacked hardware was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 33 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Center Wing Outboard Wing Fitting to Skin Panel Assembly. The structure is an aluminum stack-up of tapered thickness. The area subject to survey inspection is approximately 0.30" thick. The subject hole is sized by Engineering at 0.2460"/0.2500" for HiLok bolt installation.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy drill plate and fixturing to facilitate Spacematic, air driven drill power head, Freon spray-mist coolant was used from a gravity fed, hand-held delivery wand. Holes were drilled by "one-shot" spacematic method to their final size configuration and no reaming was planned nor employed. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.246771" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the low-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

* DRILL METHOD CODING: S-1 = Spacematic, One-shot, No Reaming

Spacematic, air powered drill and accessory tooling.

II. C. (Continued)

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces good final sized holes at assembly on a "one-shot" operation.

3. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 464 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.246771", is an ideal characteristic in regard to the Engineering criterion of 0.2460"/0.2500". This is an excellent series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Ten (10) holes are nearly perfect with their total spread of sixteen (16) measurements per hole having recorded the following range:

Hole #	Range	Comment
6	0.000569"	See Note*
11	0.000328"	
16	0.000569"	
18	0.000336"	
20	0.000526"	

III. A. (Continued)

Hole #	Range	Comment
21	0.000164"	
22	0.000302"	
25	0.000232"	
26	0.000326"	
27	0.000251"	

Note* Generally, a very subtle ovality at the start plane of drilling or at the exit plane is the feature accounting for otherwise perfectly drilled holes.

2. Five (5) holes exhibit bellmouth and/or taper which is very minute at the entrance plane of hole. A rather uniform straight taper is featured in these holes, diminishing in diameter as depth in the hole is acquired.

Hole #	Range	Comment
3	0.001267"	See Note **
8	0.001319"	
9	0.001328"	
15	0.001362"	
24	0.001103"	

Note** The magnitude of the bellmouth and/or taper in the aforenoted holes is only slightly over 0.001". The computer printout discloses the profile phenomenon. This grouping of holes is purposefully being discussed adjacent to the series in item III.A.1 to apprize the reader of the ability of the computer to

III. A. 2 Note** (Continued)

construct a pictorial geometric replica of the hole using very minutemmeasurement differences.

The general condition of this series of holes suggests very minor "seeking" of the tip on drill entry since the extremely slight bellmouth and/or taper is rather uniform at all axes of measurement. Occasionally operator side load is induced via handling of the power head during its duty cycle. Holes #12 and #14 show evidence of this feature and its result is generally evident in one (1) or two (2) axes and reverse bellmouthing (bellmouth at the exit plane).

3. Hole #29 is a near perfect hole. The Computer Individual Profile Printout reveals a "spike" in all four (4) measurement axes, at the exit plane of the hole. This condition resulted from a slight chamfer on deburring of the hole and is discounted as a detrimental feature of the basic hole.

4. Holes #1 and #10 have a combination of the slight bellmouth and/or taper discussed at item III.A.2 III.A.3 above. The bellmouth feature establishes the cause for the range of measurements exhibiting 0.001405" and 0.000983" respectively.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #2 and discloses a value of 0.000940" at plane level #3 on the 45^{o}-135^{o} axis. Side load enlargement at the 90^{o}-135^{o} axis was

III. B. (Continued)

most probably induced by operator handling of the drill during its duty cycle. The ovality is slight and <u>does not</u> exceed the Engineering tolerance criterion. Ovality generally for this set is very minute and exists predominantly at plane levels #1 or #4 and is the product of the bellmouth and/or taper features with regard to the shank of the holes.

Ovality was not a cause for concern on this lot. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this lot exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: Nonexistent as evidenced by profile analysis.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Holes #3, #8, #9, #15 and #24 per item III.A.2. Various other holes of this set exhibit the same condition at their entrance plane of drilling; however, none of

III. F. (Continued) the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and fitting was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 34 *

HOLE SIZE: 0.246"/0.250"

I. OVERVIEW:

A. This set of survey holes features Quackenbush drilling and final reaming of holes in a Center Wing Lcwer Surface. The structure is a mix of steel and aluminum in the stack consisting of a steel strap, lower surface wing skin panel and machined rib. Survey Team adapter tooling for the air-probe would not accommodate the complete assembly thickness; therefore, measurement data was taken through the steel strap and wing skin panel only, a thickness of 0.62". The subject hole is sized by Engineering for the final ream size at 0.246"/0.250" per Specification.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical Quackenbush Drilling, final reaming.

II. SUMMARY:

A. Reference Executive Histogram by Data Lot. The data population for this set is situated between the 0.2480"/0.250+" zone of the overall 0.246"/0.250" tolerance band. The data elements exhibit a pattern expressing the range in data measurements controlled by the bellmouth and barrelling characteristics inherent in the holes of this set.

Twenty-nine (29) holes were available in this structure for survey inspection. Reference "Executive Summary by Data Lot." This set discloses a measurement distribution whose arithmetical average is 0.249348" for the series of twenty-nine (29) holes. This value is within specification but signifies a trend mode worthy of attention to stop and/or reverse its growth. The affect of steel chip carry through into the aluminum is apparent in the barrelling feature present in the skin panel which is a faying surface component to the steel strap.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. The influence of steel chips impinging on aluminum in the assembly stack is apparent.

2. Quackenbush method of hole production produces acceptable finished holes but with relatively high percent of marginal holes.

3. Normal plug-gage inspection would not pick up the barrelling feature in the skin member.

4. Two (2) stage final reaming (reference paragraph III.A.5 for details) may help to eliminate the skin barrelling.

III. CHARACTERISTICS:

A. Hole Size: 1144 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.249348" which approaches the tolerance high limit for this set and is reflected in the geometry of these holes.

A slight bellmouth characteristic at the start vicinity of the holes and a barrelled feature in the skin panel are inherent anomalies throughout this set.

In addition, an oversized condition is reflected in the computer data of nine (9) holes. These anomalies are discussed in the following text.

1. Reference holes identified Hole #6, 7, 13, 18 and #19 along with their Individual Hole Computer Printouts. The oversize data elements of these holes are assessed as insignificant.

The maximum oversize measurements were recorded as follows:

Hole #	Maximum Measurement Readout
6	0.000138"
7	0.000138"
13	0.000086"
18	0.000181"
19	0.000026"

None of the above dimensional recordings are assessed a detriment to the quality of the affected holes. Review of the Axes measurement data discloses irregular starts in the reaming (center-seeking) to be the cause for <u>all</u> of these readings. The phenomenon is extremely small and disappears at the second plane of measurements.

2. Hole #9 and #16. Reference Individual Hole Computer Printouts.

Hole #	Maximum Measurement Readout
9	0.000165"
16	0.000169"

The oversize nature of these dimensions are insignificant to the dimensional integrity of both holes. Reference to the profile presentation of the computer data to these dimensions. Their location within the holes concludes their origin to be steel chip impingement from the outer strap into the softer aluminum skin. The feature is very slight and is geometrically presented as a minute barrelled condition in the skin panel.

3. Hole #11 is addressed as having recorded the greatest measurement in this setat 0.250440". Reference Individual Hole Computer Printout.

Center-seeking and side loading induced by the operator during the duty cycle of final reaming is assessed the cause for the oversize measurements that persist at a magnitude of 0.0001" along the 90° axis. Again, the feature is extremely small and has minimal affect on depreciation of overall hole quality.

4. Hole #14, the final hole exhibiting an oversize dimension presented its anomaly at the 90° axis of measurements and at 0.250267". The cause is assessed as chip load build up, most probably a result of momentary stall in chip clearing of the reamer.

5. In all of the aforementioned holes, the oversize has been assessed as negligible for its affect on hole quality and generally is a result of center-seeking and/or steel chip impingement into the softer aluminum member following the steel part in the assembly stack.

   In all of the above holes and <u>the</u> remainder of this set of holes which <u>are</u> not oversize in any dimensional respect, the features of bellmouthing and barrelling still persist in the steel strap and aluminum skin. The features are extremely small and for the most part do not exceed the allowable Engineering tolerance for these holes.

   An approach to eliminating the barrelled condition suggests reaming the steel to a controlled depth sufficient to clear its chip generation and retract the reamer; Then, proceed with a second (non-cutting pass) to finish the hole in the aluminum members. This approach tends to clear the hole and follow on using the steel member as a reamer guide for the softer aluminum parts following it. In the case of the small holes (1/4), the steel member in the stack is actually thicker than the hole diameter and offers significant chip generation to impinge onto the follow on parts.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #3 and discloses a value of 0.001069" on the 45° - 135° axes at plane #8. Ovality is a function of the affect of barrelling brought by the steel chip impingement into the aluminum skin member of the assembly stack. Ovality within itself does not exceed the Engineering tolerance criterion in this set. Reference to the Individual Hole Computer Printouts. All holes meet the Engineering tolerance on ovality measurements; However, the feature is a function of the bellmouth and/or barrelling characteristics and warrants attention for methods improvement toward elimination of the features.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection, via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via subsequent inspection of the head to countersink nesting of fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion of 2°.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Most of the holes of this set exhibit this feature in the aluminum skin member ot the stack. Refer to narrative at paragraph III.A.1 thru III.A.5 for details.

F. Bellmouthing: Most of the holes of this set exhibit a slight bellmouth feature at the start vicinity of reaming. Refer to narrative at paragraph III.A.1 thru III.A.5 for details.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited good interior wall texture. Several holes revealed very shallow angle rifling, not in excess of the 125AA machine finish criterion. The holes were inspected via Sight Pipe at 3X magnification. There were no chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100AA or better. Optical Surface Comparator was used for inspection and the sidewalls were smooth and shiny.

DRILL METHOD MS

RANKING NUMBER 35 *

HOLE SIZE 0.6235"/0.6245"

I. OVERVIEW

A. This set of production holes feature drilling and broaching of Main Gear Bellcrank Idler machined detail parts. The details are 2014 aluminum forgings. Measurements on the holes were taken to a depth of 1.625" into the holes. Measurements were obtained via "thru-hole" air probe and recorded on magnetic tape to ascertain hole size and geometric features. The subject holes were sized by Engineering at 0.6240 +/ 0.0005".

II. SUMMARY:

A. Twenty-seven (27) holes were available in this structure for inspection. The method of production utilized drill press and horizontal broaching machine. The parts were initially drilled at 39/64" (0.609") followed by broaching to a final size of 0.6240 + 0.0005"/-0.0000" per fabrication traveler planning instructions.

B. These holes disclose a measurement distribution whose Arithmetical Average is 0.624278" for the set of twenty-seven (27) holes. Specific details on the geometric characteristics of the holes are discussed in Paragraph III.

C. The computer data Statistical Printout for this series of holes provides clues traceable to the following for the production of these holes:

1. Samll custom designed drill fixture ensures hole interchangeability and location reliability.

* DRILL METHOD CODING: MS = Miscellaneous Systems - Track Mounted Drill

Drill Press and horizontal broaching machine.

II. C. (Continued)

2. Vertical drill press most probably employed for initial 39/64" (0.609") drill operation. Parts for checking were drawn from existing stores for the survey inspection. Drilling operation is the most likely candidate for cause of oversize dimensions within this series of holes. Reference Paragraph III. A.

3. Horizontal Broaching Machine employed for part final hole sizing.

4. Planning is good for purpose of fabrication instructions and subsequent inspection.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary by Data Lot" for this set. 2,472 data measurements were accrued for this series of twenty-seven (27) holes. The Arithmetical Average 0.624278" is well within the tolerance criterion of 0.6235"/ 0.6245" established by Engineering and naturally trends toward the high limit since the broach was sized at 0.6240" per fabrication instructions.

b. Holes #1, #4, #17 and #22 were excellent, exhibiting Arithmetical Averages of 0.624173"; 0.624176", 0.624182 and 0.624165" respectively and flawless interior wall surfaces. In addition the surface finish of the walls were "63 AA" or better via Optical Comparator.

c. Occasional dull textured ("satin finish") sidewall discontinuities were observed on the remainder of these parts. Inspection via 3X magnification Sight Pipes disclosed these areas to be correlatable by their index position (0°-45°-90°-135°) and plane depth to the <u>oversize dimensions</u> recorded on the

III. A. (Continued)

computer tape printout for these holes. Additionally, the shape of the discontinuities ("satin finish areas") as viewed visually on the parts was also discernable on the computer printout by their "clocked" position and plane depth into the hole. Although these "satin finish" areas were visually apparent they were extremely <u>subtle</u> and could only be detected on diametrical feature via air-gage measurement. Occasional very shallow angle rifling could be distinguished in these "satin finish" areas. Conclusion suggests the following:

1. The 0.609" drilling operation produced the "satin finish" discontinuities.

2. Generally the anomaly is apparent at the entrance plane and/or exit plane of the drilled hole, or both.

3. The radius of the "satin finish" area is smaller than the basic broach radius and forms a bulge in the hole sidewall that is faired smoothly into the broached final hole diameter.

4. Holes #12, #18 reveal the drill characteristic deep into the hole at plane depths #13 to #16 and #13 to #15 respectively.

5. The common feature in all of the conditions above point to drill wobble, straightness wandering or slight difference in perpendicularity, resulting in the broach failing to "clean out" the drilled hole.

d. Nine (9) holes, namely Hole #3, #7, #8, #9, #10, #15, #18, #21 and #27 have the

III. A. (Continued) "satin finish" blemish at only one (1) to three (3) locations of the ninety-two (92) measurements obtained per hole. Except for Hole #18, all exist at either the entrance or exit planes of the holes and are insignificant to overall hole quality. Refer to Individual Hole Profile Printout for details.

e. Eight (8) holes, namely Holes #5, #6, #11, #13, #14, #16, #23 and #24 are similar to item "d". There are a couple additional areas of oversize "bulges" which impinge slightly deeper into the holes but are not significant to overall hole quality.

f. Holes #2, #12, #19, #20, #25 and #26 exhibit a dispersion, frequency and depth into the hole which suggests rejection for purpose of size and hole function.

B. Ovality: Hole #12 exhibited the greatest ovality at 0.003776" for the 0^o-90^o axes and 0.003569" for the 45^o-135^o axes. Owing to the requirement for bushings at both ends of the subject holes, ovality of the reported magnitude and depth could be of Engineering concern. Holes #2, #5, #20, #23, #24 and #26 may warrant a similar concern. Except for the above noted holes, the remainder of these holes were within the tolerance bound established by Engineering.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined end faces. Perpendicularity was verified to be zero degrees (0^o) when measured with the 10X magnification Azimuth/Angle Gaging Device equipped with magnetic standoff bushing.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analysis.

E. Barrelling: None evident as indicated by the profile analysis.

F. Bellmouthing: General tendency toward "bellmouthing" and or "taper" as evidenced by individual profile analysis. Condition exceeds the allowable Engineering tolerance criterion, but is generally shallow in depth except for holes per paragraph III. A. f.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification in a few of the areas where broaching failed to clean out the initial drilled pilot hole. The finish in these areas appeared as "satin finish" texture. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and broached through a single 2.00" thick aluminum forging were satisfactorily deburred per process plan instructions.

1. Surface Finish: All holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except in the areas previously identified as having a "satin finish".

DRILL METHOD Q-2

RANKING NUMBER 36 *

HOLE SIZE: 0.199"/0.202"

I. OVERVIEW:

This set of production holes features drilling and reaming of the R. H. Nacelle Assembly. The structure is a multi-layered stack of titanium skin and steel frame member whose combined thickness in the area to be surveyed is approximately 0.25". The subject hole is sized by Engineering at 0.199"/0.202".

Drill:	0.190" diameter
Reamer:	0.1992" diameter piloted reamer
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	555 Crystal Cut @ 10:1 Water Mix
Info:	Drilling and reaming were performed in the direction of the titanium skin through to the steel frame. Inspection utilizes plug "Go" and blade "No-Go" gaging method.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy overlay drill plate, pinned and clamped to the nacelle structure to facilitate locking on the Quackenbush, air driven drill power head. Hand fed Crystal Cut 555 coolant and air were used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.190" and followed by Quackenbush, air driven drill motor and 0.1992" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.200734" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the mid-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical

Quackenbush, air powered drill & accessory tooling.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.190" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.1992" reamer.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" Gaging inspection.

III. CHARACTERISTICS:

A. Hole Size: 232 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.200734", well below the 0.2020" high limit per established Engineering Criterion. This is an excellent series of holes on size. The relative thinness of the steel and titanium members in the assembly stack precludes the acquisition of good profile data to point out meaningful trends.

Reference Computer Individual Hole Printout discloses an excellent range distribution of hole measurements. Only 0.002267" separated the maximum/minimum measurement recording for this set of holes.

1. The spread of measurements taken at eight (8) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000255"	16	0.000302"
2	0.000198"	17	0.000517"
3	0.000190"	18	0.000411"
4	0.000181"	19	0.000334"
5	0.000381"	20	0.000353"
6	0.000371"	21	0.000243"
7	0.000448"	22	0.000431"
8	0.000310"	23	0.000263"
9	0.000569"	24	0.000164"
10	0.000276"	25	0.000319"
11	0.000672"	26	0.000089"
12	0.000078"	27	0.000332"
13	0.000414"	28	0.000360"
14	0.000184"	29	0.000388"
15	0.000642"		

Note: Individually, only four (4) holes, identified Hole #9, #11, #15 and #17 reveal a range value that exceeds 0.0005".

2. This series of holes are exceptionally good on roundness considering the fact of horizontal drilling/reaming. Side load ovality is not apparent in the finished holes.

3. Individual Histograms disclose a Normal Gausian Distribution on the measurement population and all are grouped in the vicinity of the mid-point tolerance range. The Executive Histogram for the entire data set discloses a similar distribution.

   Operator care and skill in tool handling are apparent in the end product quality of this series of holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #11 and recorded at 0.000552" at Level #2 on the 45°-135° axes. This value is negligible on hole quality. A faying surface interface from titanium to steel occurs at this level thus resulting in an ovality enlargement of the hole most probably the result of extremely slight gap in the stack clamp-up.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy drill plate with long engagement bushings assures perpendicularity of the holes with regard to the structure. This series of holes were checked by by gaging via sample fastener installation. The holes were verified to be normal (90°) to the longitudinal axis of the holes with regard to the drilled/reamed nacelle structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None evident via profile analyses. The material thickness combination at 0.25" precluded acquisition of more measurements for profile analyses.

F. Bellmouthing: None evident per profile analyses. Occasional slight enlargement at either the entrance and/or exit planes of the holes is evident but not severe enough to consider the feature as bellmouth. It exists as either lead-in wobble or irregular break-out loading on the holes.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were only shallow angle rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "100 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD MS

RANKING NUMBER 37 *

HOLE SIZE: 0.3120"/0.3140"

I. <u>OVERVIEW</u>:

A. This set of production holes features drilling and reaming of the Hinge Assembly, Main Landing Gear Inboard Door, Forward. The structure is a stack-up consisting of steel outer face lugs sandwiching three (3) aluminum filler plates of 0.125" thickness. The entire stack, approximately 1.00" thick, was inspected by "thru-hole" air probe to ascertain hole size and geometric features. The subject hole is sized by Engineering at 0.3120"/ 0.3140".

II. <u>SUMMARY</u>:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized a small custom portable drill fixture to assure hole location. Holes were drilled by machine shop vertical turret drill press and reamed by the same technique to an undersize dimension. Final reaming to full drawing size was accomplished by hand-held air powered drill motor.

B. These holes disclose a measurement distribution whose Arithmetical Average is 0.314626" for the set of twenty-nine (29) holes. All of the holes of this set were oversize and exhibit a classic example of "barrelling" throughout the aluminum central portion of the structure. Specific details on the geometric characteristics of the holes are discussed in paragraph III. Generally, the outer steel shell, representative of the <u>entrance</u> and exit planes of the parts, are within the Engineering tolerance criterion or are only slightly above the Engineering tolerance. Holes #9, #15 and #19 are classic examples of "barrelling" within the structure.

* DRILL METHOD CODING: MS = Miscellaneous System - Track mounted drill
Vertical Turret Drill Press w/small custom fixture for drilling.
Hand-held air driven drill using a reamer for final hole sizing.

II. (Continued)

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Small custom designed drill fixture ensures interchangeability and location reliability.

2. Vertical Turret Drill Press and accessories are adequate for hole production but long hole engagement of the central section (aluminum) exposed to the steel outer face chips results in barrelling.

3. Hand-held air powered drill motor final reaming contributes to the creation of oversize holes and "barrelling."

4. Detail planning is satisfactory for work instructions and inspection requirements.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary by Data Lot" and "Executive Summary Histogram". The Arithmetical Average for the entire set of twenty-nine (29) holes is 0.314626"; also, the measurement dispersion of the Histogram crowds the limit of the tolerance and spills over into the out of tolerance condition. Both of these features are the result of the "barrelling" in the center aluminum portion of the hardware stack. Most probably cause for the oversize and "barrelling" features are:

1. Steel chip impingement into the relatively long engagement soft center portion aluminum.

2. Instability of reaming using hand-held drill motor contributes to the enlargement of the holes

III. A. (Continued) 2. (Continued)

in the <u>steel</u> at the <u>entrance</u> plane of the parts and spurs in the hole profile induced by side loads.

b. Hole #23, the largest of the series at 0.317112" illustrates the instability phenomenon related to hand-reaming. Reference Individual Hole Profile computer printout. The lower spike suggests a side load on the reamer just prior to entering the steel since the "barrelling" characteristic is <u>missing</u> in this hole.

c. True isolation of hole profile features suggest that measurements on sample parts be taken as follows to isolate "barrelling" feature:

1. Perform measurements of same nature with air probe after drilling.

2. Perform measurements after machine reaming.

3. Perform measurements after hand reaming.

4. Compare the controlled samples.

B. Ovality: Hole #12 recorded the largest ovality of the set at 0.002259" on level #6 of the 0^{o}-90^{o} axes. This hole also supports the "spur" phenomenon proposed as a result of hand reaming side loads. Reference Individual Hole Profile Printout. "X" figures in the profile equal one thousandth of an inch (.001") and figures to the far right of the column equal tenths of thousandths of an inch (0.0001"), i.e., "XX-----4" equals 0.0024". The "barrelling" feature overwhelmed all other characteristics in this set of holes.

III. (Continued)

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the bulkhead and fitting machined face (interface surface). Perpendicularity was verified to be zero degrees (0^{o}) to one quarter degree ($1/4^{o}$) when measured with the 10X magnification Azimuth/Angle Gaging Device. All holes were well within the Engineering tolerance criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analysis.

F. Bellmouthing: Generally evident as indicated by profile analysis. This characteristics was precipitated as a result of hand reaming and operator instability. Reference Item III. A. d.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through stacked arrangement of bulkhead to fitting was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 38*

HOLE SIZE: 0.199"/0.202"

I. OVERVIEW:

This set of production holes features drilling and reaming of the Nacelle Assembly. The structure is an aluminum Stringer (Skin was removed for this survey) whose thickness in the area to be surveyed is 0.350"/0.380". The subject hole is sized by Engineering at 0.199"/0.202: for installation of Huck Lok Bolts.

Drill:	0.190" Diameter
Reamer:	0.1992" Diameter
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	555 Crystal Cut (Dip tool into full strength coolant)
Info:	Inspection utilizes plut "Go" and blade "No-Go" gaging method.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a heavy leaf drill plate, pinned and clamped to the Nacelle to facilitate locking on the Quackenbush, air driven drill power head. Hand fed Crystal Cut 555 Coolant and air were used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.190" and followed by hand reaming via hand held air motor and 0.1992" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.200652" for the set of twenty-nine (29)

* DRILL METHOD CODING: Q-2 = Quackenbush - Air Power Reamer, Mechanical

Quackenbush, air powered drill and accessory tooling.

II. B. (Continued)

holes. This value is an excellent feature since it resides at the mid-point vicinity of the Engineering tolerance range. <u>All</u> of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.190" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.1992" reamer.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" Gaging inspection.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 464 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.200652", well below the 0.2020" high limit per established Engineering Criterion. This is an excellent series of holes on size and shape features considering the fact that hand reaming was employed to achieve the final hole size.

Reference Computer Individual Hole Printout discloses an excellent range of hole measurements for a material thickness at 0.35"/0.38".

III. A. (Continued)

1. The spread of measurements taken at sixteen (16) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000250"	16	0.000328"
2	0.000414"	17	0.000810"
3	0.000500"	18	0.000828"
4	0.000216"	19	0.000405"
5	0.001009"	20	0.000250"
6	0.000198"	21	0.000362"
7	0.000405"	22	0.000664"
8	0.000353"	23	0.000405"
9	0.000888"	24	0.000603"
10	0.000853"	25	0.000397"
11	0.001457"	26	0.000397"
12	0.000905"	27	0.000302"
13	0.001724"	28	0.000621"
14	0.001198"	29	0.000336"
15	0.000090"		

2. Five (5) holes, identified hole #1, #4, #6, #15 and #16 are virtually perfect specimens. Reference to Individual Computer Printout discloses their individual profiles to be free of imperfections. Refer ' ‘tem III.A.1 above for the specific range distribution on hole measurements.

3. Four (4) holes identified Hole #10, #11, #12 and #24 reveal a tapering enlargement feature and chip scarring inside of the holes. The taper is greatest at the top of the hole and diminishes as it approaches the exit plane of the dr drill/reamer. During drill and reaming, a titanium skin overlaid the stringer; therefore, a titanium chip is rationalized as the most probable cause for the spikes in

V. A. 3. (Continued)

the data values of Holes #11, #12 and #24 at their second plane of measurements. On Holes #10 and #11 the spike is limited to plane #2. On Hole #12 the feature exists as a spiral between its second and third plane levels of measurements. On Hole #24 the scar is of varying depth around the hole at plane level #2. Reference Individual Computer Printout for confirming evidence of the aforenoted conditions. The imperfections are very minute and do not exceed the permissible Engineering tolerance.

4. Four (4) holes, identified Hole #8, #13, #25 and #29 exhibit a slight bellmouth condition at their drill/reaming entrance plane vicinity. As in Item III.A.3 above, titanium chip impingement during drill and/or reaming is suggested as cause for this very slight imperfection in the holes. Since the tolerance allowable has not been violated, hole quality depreciation has not been compromised.

5. Holes #17, #18, #22 and #28 exhibit a bellmouth and/or taper in the vicinity of their drill/reamer exit planes. Slight overheating due to coolant starvation is suggested as most probable cause for this feature in the noted holes since the enlargement is relatively constant and affects all axes of measurements. Hole quality has not been affected since the condition is extremely slight and well within the tolerance allowable per Engineering.

V. (Continued)

B. Ovality: Maximum recorded ovality within the set occurred at Hole #11 and recorded at 0.000922" at level #2. This value is negligible on degradation of hole quality as has been reported per item III. A. 3.

C. Perpendicularity: Hole size, 0.199"/0.202" would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Bellmouthing: Evident in very subtle amounts as indicated by Holes referenced in the note at item III.A.3. Various other holes of this set exhibit the same condition at their entrance and exit planes of drilling: however, none of conditions exceed the allowable Engineering tolerance.

E. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were only infrequent perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

F. Burrs: This set of holes was drilled through a laminated stack. The skin was removed and the stringer deburred satisfactorily in the normal process plan work instructions.

G. Surface Finish: 11 holes of this set exhibited a surface finish of approximately "100 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 39 *

HOLE SIZE: 0.6245"/0.6260"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the wing Front Spar Assembly. The noted fittings are 0.500" thick with the subject hole sized at 0.6245" by Engineering.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production was custom fixturing to assure hole location and interchangeability. The fixture was loaded horizontally. Drill plates incorporated locator bushings and dimple pilots for the holes. Drilling was accomplished with a track mounted Lazy Arm Vertical Farnham Drill integral to the fixture. Reaming to full hole size 0.6245"/0.6260" was accomplished by piloted reamer. Measurements of the subject holes were obtained by the Survey Team using a "thru-hole" air probe.

B. This set discloses a measurement distribution whose arithmetical average is 0.626743" for the set of twenty-nine (29) holes. All of the holes were oversize. Reference to the "Executive Summary by Data Lot" discloses a measurement spread range of 0.003517" for the set; also, the "Executive Summary Histogram Distribution" reveals the measurements to be in excess of the Engineering high limit 0.6260". Reason for the oversize condition on this set of holes is discussed in paragraph III.A.

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

* DRILL METHOD CODING: Q-1 = Quackenbush - Handheld Air Power Reamer

Vertical Lazy-Arm Farnham drill w/hand-held, air powered reaming out of fixture.

II. C. (Continued)

1. Custom designed fixture ensures interchangeability and location reliability.

2. Lazy Arm Farnham Drill, air powered track mounted and integral to the fixture used for drilling.

3. Hand-held air powered drill motor, piloted reamer for final hole reaming.

4. Planning is adequate to ensure model and serial number traceability for assembly that is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary" for this set. 580 measurements were accrued for this series of holes. The Arithmetical Average" for the set is 0.626743" with related cause defined in the following text.

b. All twenty-nine (29) holes were oversize to some degree with the lease oversize at Hole #15, 0.626017"/0.626422"; Hole #25, 0.626172"/0.626603"; and Hole #2, 0.626328"/0.626802".

c. Hole #20, the largest, reveals a size of 0.626457"/0.628716". Refer to the "Statistical Printout" for individual hole sizes and characteristics.

NOTE: Refer to the "Executive Summary Histogram" and the "Individual Hole Histograms". All data elements with few exceptions are at, or above, the 0.6260" high limit. Areas suspect for cause of the oversize are"

1. Planning: The assembly after drilling and reaming to size is

III. A. (Continued)

disassembled, deburred then reassembled for partial riveting. Shift of the "line reamed", close tolerance holes (very slight) is possible.

2. Riveting of the fitting causes a subtle position shift of the close tolerance holes. This shift was verified by the fact that a close tolerance plug could not be passed through the "line-reamed" tongues of the subject fittings at station 27 after riveting. Hand reaming using a piloted reamer and hand ratchet wrench driven was accomplished to re-establish the "line reamed - through hole feature" of the assembly.

3. Hand line reaming after riveting resulted in the slight oversize and oval conditions of these holes.

4. All of the holes reveal a very slight taper at either the entry plane of the reamer or its exit plane. This slight taper (or bellmouth), results from the execution hand reaming per Item #3 above.

B. Ovality: The maximum ovality of the set occurred at Hole #4 and was recorded at 0.002371". Ovality generally throughout the set ranges only in tenths of a thousandth of an inch and is suggested to be largely the result of hand-ratchet reaming to achieve re-alignment of the fitting holes.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machine surface

V. C. (Continued)

C.	(Continued)	of the fittings. Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.
D.	Straightness:	Straightness is within Engineering design tolerance as indicated by the profile analysis.
E.	Barrelling:	None evident as indicated by profile analyses.
F.	Bellmouthing:	Generally evident as indicated by profile analyses. This characteristic was precipitated as a result of hand-ratchet reaming to achieve close tolerance hole re-alignment.
G.	Hole Texture:	Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.
H.	Burrs:	This set of holes, drilled and reamed through a clevis arrangement of flanges, was deburred satisfactorily in the normal process plan work instructions.
I.	Surface Finish:	All Holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this Inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 40 *

HOLE SIZE 0.2500"/0.2540"

I. <u>OVERVIEW:</u>

A. This set of production holes features drilling of a structure, approximately 0.625" thick. This is an aluminum stack-up of three (3) laminates (-001 machined fitting, web and -002 machined fitting). The subject hole is sized by Engineering at 0.2500"/0.2540" for HiLok fastener installation, Type II, per STP 2006.

II. <u>SUMMARY:</u>

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a pilot drilled -001 machined fitting to assure basic hole location. These holes were drilled on assembly by hand-held, air powered drill motor for all drilling operations. Reaming was not planned nor performed to obtain the final hole sizing. Several drilling operations were performed to arrive at the final hole size. <u>Drill stalling</u> was a frequent phenomenon owing to insufficient chip clearance between the accessory drill block bushing and the entrance surface of the structure being drilled. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. These holes disclose a measurement distribution whose arithmetical average is 0.249554" for the lot of twenty-nine (29) holes. <u>Nearly all</u> of the holes of this series <u>failed</u> to achieve a size configuration in compliance with the low limit (0.2500") criterion established by Engineering. The holes were of good quality but undersize. The undersize condition of the entire set leads to the suspicion that a 1/4" drill, sized at its acceptable low limit tolerance (0.2490"), per American Standard Twist Drill Tolerance, was used in the final drilling operation. The geometric features of this set of holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

* DRILL METHOD CODING: H-1 = Hand-Held Drill, No reaming.
Pilot drilled -001 machined fitting. Hand-held, air powered drill. No reaming.

2. Hand-held, air powered drill method and accessories produces good basic holes. Accessory tooling was a drill block, secured by cleco clamping in a preceding hole to stabilize the tooling against "roll-over" during drilling. Drill block is similar to spacematic drill locating.

3. Reaming was not planned nor employed to obtain the final hole size.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 808 data entries were accrued for the this series of twenty-nine (29) holes. The arithmetical average for the set is 0.249554", well below the 0.2500" low limit per established Engineering Criterion. The suspected cause for virtually all of the holes of this set being undersize has been stated as an <u>undersize drill</u>.

a. A 1/4" drill sized at 0.2490" is suspected as the drill used for the final hole since all of the holes are clustered at 0.2490" to 0.2499" measurement distribution.

b. Holes #3,#9 and #23 are examples approaching the largest hole sizes. It is apparent via the Individual Hole Profiles that these holes are tapered from either the start plane of the drilling or at drill exit plane. Most probable cause of the taper (although only 0.001" in magnitude) is chip loading from drill stalls. The operator was frequently observed backing out a stalled drill by hand to clear the hole.

c. Holes #1, #4 and #5 and #13 are examples of side loading induced by operator instability during drilling.

d. Individual Histograms coupled with the Individual Hole Profiles of these holes disclose that side loading effect on holes and the lead in or break-out taper are the physical features which permitted a few holes to approach the low limit of the Engineering tolerance.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #23 and recorded at 0.002267" at Level #7. Ovality was induced by irregular break-out load. The condition is extremely negligible in magnitude and <u>did not</u> exceed the allowable Engineering tolerance.

Throughout the set ovality is well below 0.0006" in magnitude and is well within the tolerance allowable for this feature. In cases where the ovality exceeded 0.001", Holes #7, #20, #23 and #28, the condition was precipitated by the taper discussed in item III. A. b. above. There are no ovality conditions in this set which exceed the Engineering Criterion.

C. Perpendicularity: Hole undersize condition would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Holes #8 and #25 Individual Profiles reveal a very subtle barrelling feature. Both holes are the result of drill operator instability and the feature does not exceed the tolerance permitted by Engineering.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Holes #9, #10 and #16. Various other holes of this set exhibit the same condition at either their entrance or exit planes of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-3

RANKING NUMBER 41 *

HOLE SIZE: 0.3090"/0.3130"

I. <u>OVERVIEW:</u>

A. The structure is an all aluminum stack-up approximately 0.60" thick and the subject hole is sized by Engineering at 0.3090"/0.3130" after finish reaming.

II. <u>SUMMARY:</u>

A. Twenty-nine (29) holes were available in this structure for survey inspection. The sequence of producted directed preliminary reaming of the holes to prepare them for cold working; cold work split sleeve and mandrel expansion of the holes; hand reaming to the final size for fastener installation. Hole expansion was accomplished via air powered tooling and the reaming operations by hand held air powered drill motors driving piloted tip reamers.

B. All of the holes in this set except Hole #13 are within the Engineering criterion of 0.3090"/0.3130".

Reference Executive Summary for Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.310151" for the set of twenty-nine (29) holes. This value is excellent since it resides at the low-limit vicinity of the tolerance range. There is an inherent feature of bellmouthing apparent throughout the set.

Specific discussion on the geometric characteristics of the holes are discussed at paragraphs III along with rationale disclosures for most probable causes for the bellmouth characteristic in this series of holes.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following:

1. Hand-held air powered drill motors for final reaming operations.

* DRILL METHOD CODING: H-3 = Hand Held Drilling; Cold Worked Hand Held Reaming

NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.3090" (tip) and 0.3110" (shank).

2. Lack of assist tooling to stabilize reamer and powerhead.

3. Affect of reaming through all aluminum in the assembly stack is apparent.

III. <u>CHARACTERISTICS:</u>

A. Hole Size: 1068 data measurements were accrued from the twenty-nine (29) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.310151" for the set which is an excellent and desirable characteristic since it resides at the low vicinity of the Engineering Tolerance Criterion. Reference Individual Hole Computer Printouts. Virtually all holes of this set exhibit a chronic slight bellmouthing feature at the start plane of measurements and disappear as depth in the hole is achieved. The feature is slight and within tolerance except for Hole #13 as follows:

1. Hole #13 discloses the only measurement in this set in excess of the Engineering tolerance. It occurs at plane level 1 at the 135° axis and is recorded at 0.313138". This dimension has been discounted as a detriment to hole quality since it occurs at the entrance plane of the reamer and is completely gone at the next plane of measurements. Slight "center-seeking" at the engagement of the reamer to the hole is assessed the cause for this bellmouth characteristic.

2. Holes #1, 2, 6 and 7 are good examples illustrating a bellmouth condition at their entrance areas of the reamer and followed by a similar feature in the vicinity of the exit planes of the reamer. In all cases, the bellmouth feature is predominant at the 0° and 135° axes at the top and bottom

of the holes. This phenomenon illustrates the affect of slight side-loading in the hole via very subtle movement (shift) by the operator during the duty cycle of reaming. All of the aforementioned holes are within tolerance. However, the trend exists and results from insufficient stabilizing tooling. A supplementary tooling drill plate with integral reamer guide bushing also serves to reduce center-seeking of the reamer by affording a more stable path for the reamer.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #6 and disclosed a value of 0.002267" on the 45^{o} - 135^{o} axes at level 1. Ovality at this hole did not exceed the Engineering tolerance criterion and is the product of the bellmouth feature at the entrance plane of the reamer due to "center-seeking".

Hole #13 exhibited one measurement at 0.313138" at level 1. Refer to narrative at par. III.A.1 for details.

Ovality was not cause for concern on this set.

C. Perpendicularity: Severl holes within the series were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were normal (90^{o}) to the longitudinal axis of the hole with regard to the outer surface of the wing structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: All holes are bellmouthed in association to their entrance plane characteristic. Refer to narrative at paragraph III.A.1 and III.A.2.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited excellent interior wall texture. Inspection was performed with Sight

Pipes at 3X magnification. There were no chatter marks, rifling, scratches nor scoring in these holes.

H. Burrs: There was no evidence of burrs in the stack-up of materials in the assembly.

I. Surface Finish: All holes of this set exhibited a surface finish of 100AA or better. Optical surface comparator was used in this inspection. Surface was generally smooth and shiny.

DRILL METHOD MS

RANKING NUMBER 42 *

HOLE SIZE 0.5005"/0.5015"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of Steering Joint Cross, machined detail parts. The details are 7075 Aluminum forgings. The subject hole is sized by Engineering at 0.5005"/0.5015". Measurements were taken on the holes at 0.100" depth and followed by 0.0625" increments thereafter to a depth of 0.540" into the parts. The parts were rotated 180° and a repeat of measurements was accomplished; hence, Hole #1 and #2 is equivalent to one (1) through hole in a given detail part. The hole selected for measurement runs parallel to the 1.748"/1.745" length dimension and identified datum -A-.

II. SUMMARY

A. Fifteen (15) machined detail parts were used for inspection to accumulate a set of twenty-nine (29) holes. The details are products of numerical controlled milling and boring. Measurements were taken using a "thru-hole" air probe.

B. Overall characteristics of the holes of this set were of excellent quality with individual attributes discussed in detail in paragraph III. Three (3) detail parts exhibited slightly oversize holes. The holes of these parts are identified Hole #11/#12; Hole #21/#22; Hole #24/#25 and will be discussed in paragraph III.A. The Arithmetical Average for the entire set of twenty-nine (29) holes is 0.501167" which is the nominal value considering an Engineering tolerance spread, 0.5005"/0.5015".

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the produccion of excellent holes:

* DRILL METHOD CODING: MS = Miscelianeous Systems - Track mounted drill
Numerical controlled milling & boring. Numerically controlled reaming.

1. The consistency of numerically controlled machining is evident in the Histogram profiles of the measurement distribution on the holes.

2. Finish of the holes attest proper speed, feed and condition (sharpness) of the cutting reamer.

3. Detail planning is clear and concise for producibility requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. As previously stated, three (3) detail parts account for most of the oversize holes. Although oversize, the individual hole series of measurements reveal generally only 0.0005" or less variation throughout their entire length. Unknown is the total quantity of parts which represented the initial machining run; therefore, speculation suggests possible starvation of coolout resulting in heat up of the cutting tool (reamer) resulted in the oversize condition as follows:

Hole #11,0.501672"/0.501940"; Hole #12, 0.501664"/0.502250".
Hole #21,0.502086"/0.502534"; Hole #22, 0.502095"/0.502319".
Hole #24,0.501379"/0.501862"; Hole #25, 0.501302"/0.501853".

NOTE: Only 0.0005" or less separates the measurements representative of the full length (1.745"/1.748") of the holes in the detail parts.

Hole #13, 0.501578"/0.501940" exhibited an oversize range of 0.000362" and was oversize through only half the total length of the part.

b. Holes #4 and #17 are too insignificant to discredit the quality of the hole

size. Cause of the oversize spur is chip scarring since it occurs at the entrance plane and at very shallow depths thereafter and are sporadic.

B. Ovality: This entire set of holes exhibits very good ovality characteristics. Considering the length of the bore; an internal 90° intersection which creates irregular drill/reamer breakout and re-entry; and an escape path for coolant via the intersecting hole, ovality is excellent. Ovality is generally expressed via the profile analyses at 0.0005" or less.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the hole extremity machined end faces. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Very slight evidence of barrelling by profile analyses on Holes #3, #4 and #18. On Holes #3 and #4 the characteristic is predominantly only in one axis, therefore they are not truly representative of barrelling perse: Hole #18 is the nearest to true barrelling since the evidence is in all four (4) axes.

F. Bellmouthing: Isolated via profile analyses, reference Holes #19 and #28.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited an excellent interior wall texture. There were no surface blemishes evident when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This condition did not exist. Deburring was accomplished per normal in-process work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish approximately "32 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 43 *

HOLE SIZE 0.1900"/0.1940"

I. OVERVIEW:

A. This set of production holes features drilling of a structure, approximately 0.625" thick. This is an aluminum stack-up of three (3) laminates (-005 machined fitting, web/doubler and -006 machined fitting). The subject hole is sized by Engineering at 0.1900"/0.1940" for HiLok fastener installation, Type II, per STP 2006.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a pilot drilled -005 machined fitting to assure basic hole location. These holes were drilled on assembly by hand-held, air powered drill motor for all drilling operations. Reaming was not planned nor performed to obtain the final hole sizing. Several drilling operations were performed to arrive at the final hole size. Drill stalling was a frequent phenomenon owing to insufficient chip clearance between the accessory drill block bushing and the entrance surface of the structure being drilled. Inspection measurements were obtained via "thru-hole" air probe.

B. These holes disclose a measurement distribution whose arithmetical average is 0.189329" for the set of twenty-nine holes. All holes of this set are below the low limit (0.1900") established by Engineering. The undersize condition of the entire set leads to the suspicion that a 3/16" drill, sized at 0.1875, was used in the final drilling operation. The geometric condition of this set of holes is discussed in detail at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Hand-held, air powered drill method and accessories produces good basic holes. Accessory tooling was a drill block, secured by cleco clamping in a preceding hole to stabilize the tooling against "roll-over" during drilling. Drill block is similar to spacematic drill locating.

* DRILL METHOD CODING: H-1 = Hand-held drill, No reaming. Pilot drilled -005 machined fitting, hand-held, air powered drill. No reaming.

3. Reaming was not planned nor employed to obtain the final hole size.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: This set exhibited an arithmetical average of 0.189329" for the series of twenty-nine (29) holes. <u>All</u> of the holes were undersize to the Engineering criterion of 0.1900" minimum.

a. A 3/16" drill sized at 0.1875" is suspected as the drill used for the final hole since all of the holes disclose a 0.1885 to 0.1904" measurement distribution.

b. Holes #3,#4 and #6 are examples approaching the largest hole sizes. It is apparent via the Individual Hole Profiles that these holes are tapered from the start plane of the drilling to the drill exit plane. Most probable cause of the taper (although only 0.001" in magnitude) is chip loading from drill stalls. The operator was frequently observed backing out a stalled drill by hand to clear the hole.

c. Holes #8, #13 and #27 and #29 are examples of side loading induced by operator instability during drilling.

d. Individual Histograms of these holes disclose that only the side loading effect on holes such as #13 and #27 and occasional lead in or break-out taper allowed any of these holes to reach the <u>low</u> limit (0.1900") tolerance of the Engineering.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #18 and recorded at 0.001103" at Level #7. Ovality was induced by irregular break-out load. The condition is extremely negligible in magnitude and only <u>barely</u> achieved the low limit tolerance level.

Throughout the set ovality is well below 0.001" in magnitude and is well within the tolerance allowable for this feature.

C. Perpendicularity: Hole undersize condition would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None evident as indicated by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Holes #3, #4 and #6. Various other holes of this set exhibit the same condition at either their entrance or exit planes of drilling.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD MS

RANKING NUMBER 44 *

HOLE SIZE 0.4995"/0.5005"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Elevator Trim Tab Arm. The machined detail parts are 2024T351 aluminum bar, 0.250" thick and sized by Engineering at 0.4995"/0.5005". Measurements on the holes were accomplished using a "thru-hole" air probe. Owing to the relative thinness of this detail part only one plane of measurements was taken.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this set of detail parts for inspection. The method of production was verticaldrill press. Drill and reaming were accomplished with a small custom fixture designed to hold and locate the part for drilling and reaming.

B. Owing to a relatively thin part, trend data by multiple planes down through the thickness of the part could not be achieved. Three (3) holes of this set revealed oversize conditions ranging from 0.000397" at Hole #8, to 0.001302" at Hole #7 and 0.000828" at Hole #4. The characteristics of this set of holes is discussed in Paragraph III.

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Small custom fixturing ensures interchangeability and location reliability.

* DRILL METHOD CODING: MS = Miscellaneous Systems,
Track mounted drill.

Vertical drill press in Cessna machine shop. Reaming with custom fixture.

II. C. (Continued)

2. The Executive Summary Histogram reveals the data distribution utilizing the full tolerance spread suggests possible drill/reamer fixture very slight "use wear".

3. The "Executive Summary by Data Lot" reveals the average of all measurements to be 0.500082", centered about the tolerance spread, an ideal characteristic for hole size.

4. Detail planning is excellent for the definition of the operational steps required to produce the part.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: Three holes, #4, #7 and #8 were oversize slightly. Insufficient data elements were gathered for this detail part to fully be able to pinpoint the random cause for three oversized holes. Additional data would have provided clues for trend conditions and specific causes. It is suggested that the oversize condition for this set, (3 holes), was fixture position for the start of reaming. Slight offset alignment between the vertical centerline of the machine and the part fixture.

B. Ovality: Hole #19 recorded the most ovality at 0.002112". Suggested cause is the same as in "A" above. Ovality predominately is in tenths of a thousandth for this set of holes and is well within the normal range for the tolerance established for these holes.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined face (interface surface). Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

III. (Continued)

D.	Straightness:	Insufficient data elements to establish a profile.
E.	Barrelling:	Insufficient data elements to establish a profile.
F.	Bellmouthing:	None perceptible for engagement of the air-probe into the hole. Insufficient data points to establish a profile for analysis.
G.	Hole Texture:	Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.
H.	Burrs:	Deburring was satisfactorily accomplished per direction of the detail planning for part fabrication.
I.	Surface Finish:	All holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-3

RANKING NUMBER 45 *

HOLE SIZE 0.3125"/0.3135"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Carry Thru Spar Assembly.

The structure is an aluminum to steel laminated stack-up approximately 0.550" thick at the area for the hole survey inspection. The subject hole is sized by Engineering at 0.3120"/0.3135".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized custom fixturing to assure hole location. Holes were drilled by Quackenbush air-powered drill and final sized on the holes using the Quackenbush and 0.3125" core drill. No reaming used for final hole sizing. Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose Arithmetical Average is 0.312705" for the set of twenty-nine (29) holes. Paragraph III. provides details specific to hole quality.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes.

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush drill method and accessories producing good preliminary holes at 0.250" then raised to 19/64".

3. Quackenbush air powered drill method utilizing a 0.3125", 3 fluted Cleveland Forge Core Drill produces good final sizing of this lot of holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/ "No-Go" gaging acceptance on holes.

* DRILL METHOD CODING: Q-3 = Quackenbush - One Shot Quackenbush air driven. No reaming.

III. CHARACTERISTICS:

A. Hole Size:

a. This series of holes were of excellent quality on hole size despite the condition of material stack-up being aluminum and steel. The Arithmetical Average 0.312705" is ideal, since 0.312750" is the Engineering midpoint range of the tolerance criterion.

b. Six (6) holes, namely Holes #7, #9, #15, #16, #19 and #25 reveal oversize measurements on their Individual Computer Statistical Printouts. These oversize recordings have been discounted via date analysis owing to the fact that Level #4 on the data is representative of the aluminum to steel interface. Material gap on clamp-up for hole measurement results in the air probe "sensing" this area as an oversize condition in the hole. It is not. It was predicted and noted during the course of hole measurements. These predictions were disclosed to the area crew chief and demonstrated; therefore, the subject holes are judged satisfactory.

c. Hole #20 disclosed one measurement at 0.316629" (Reference Executive Summary by Data Lot and Individual Computer Printout for Hole #20 at 135 degrees alignment, third level). This phenomenon is suggestive of a steel chip gouge into the aluminumb wall of the hole during its exit path along the drill flute. One (1) "scar" within the hole is not restrictive enough to discredit the dimensional integrity of Hole #20.

d. Hole #29 yields a complete series of oversize dimensions at its first plane of measurements. The condition actually was a slightly excessive deburring chamfer on the start (entrance plane) of the drilled hole. The characteristic disappeared completely at the next measurement plane.

e. Hole #24 reveals two (2) planes of oversize dimensions. This is the only truly oversized hole of this set. Data analysis reveals this hole to be "tapered," beginning at Level #1 and progressively growing larger with depth.

Reference to the Individual Computer Printout for Hole #20 at the 0^o, 45^o, 90^o and 135^o alignment measurement readings and Hole Profile disclosures confirm the "taper" analysis conclusion.

B. Ovality: The greatest ovality occurred at one of the oversize holes; namely, Hole #20 and was the result of the steel chip gouge influence at 0.004029" at the 45^o-135^o axes planes.

Holes #9, #16 and #29 recorded an ovality measurement in excess of 0.001" but have been discounted as cause for concern via narrative presented in paragraph III.A. b; c; and d.

Ovality generally is good with the distribution ranging below 0.0005".

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the structure station plane face. Perpendicularity was verified to be zero degrees (0^o) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analysis.

F. Bellmouthing: General tendency toward "bellmouthing" and or "taper" as evidenced by individual profile analyses but within the allowable Engineering tolerance criterion.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through a stacked arrangement of fuselage station frames, doubler and fitting were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 46 *

HOLE SIZE: 0.5005"/0.5025"

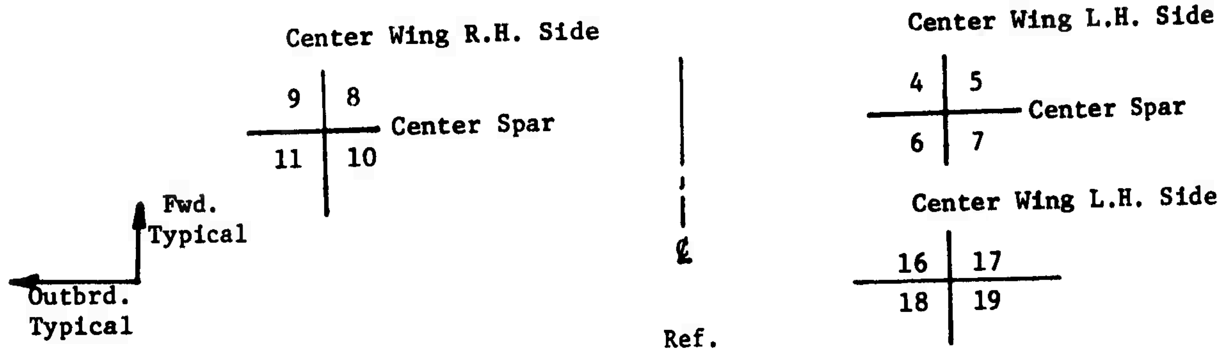
I. OVERVIEW:

A. This set of survey holes features Quackenbush drilling, cold-work split sleeve/mandrel expansion and Quackenbush final reaming in a Center Wing Lower Surface Pylon mounting holes. The structure being surveyed is an all aluminum stack consisting of the lower wing skin, center spar cap and very heavy fitting. The approximate thickness is 1.4" through the stack. The fitting mounting on the outer surface of the skin is not included in the stack nor measurement inspection. Perpendicularity is maintained via heavy tooling coordinated to the machining of the fittings on the back of the stack and the outer pylon fitting.

The subject hole is sized by Engineering at 0.474"/0.477" as the starting hole for cold-working per specification and the final ream size at 0.5005"/0.5025".

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand-held Air Power Reamer Quackenbush drill, cold-work split-sleeve/mandrel expansion and Quackenbush final reaming.

View looking up at the Center Wing Lower Surface



The assembly of the center wing structure was controlled by a very good individually serialized manufacturing Log Plan. Instructions were clear and concise for work tasks and inspection; including, mandatory AFQA inspection points.

Heavy custom tooling coordinated to the main landing gear trunion fitting hole pattern and the fixture provides a stable, accurate and reliable means to mount the Quackenbush power unit and ensure proper location/interchangeability of the pylon mounting holes. A siphon fed air-mist coolant system is employed during the drilling/reaming operations.

II. SUMMARY:

A. Reference "Executive Histogram by Data Lot." The data population for this set is fairly evenly distributed over the entire 0.002000" range of the Engineering tolerance. This characteristic results from the multiple set-ups to acquire the set and the slight bellmouth feature and chip load tapers that are present in the set. Variations are extremely small and the overall quality of this set is geometrically very good.

Nineteen (19) holes were available in this structure for survey inspection. All of the holes of this set meet the established Engineering criterion. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.501438" for the series of nineteen (19) holes. This value is very good since it resides at the mid vicinity of the tolerance range. The affect of deep reaming with traces of chip build up and minor barrelling is apparent in some holes of this set.

Specific discussion on the geometric characteristics of the holes are discussed in paragraph III along with rationale disclosures on overall quality.

B. The Computer Statistical Printout for this series of holes provide composite clues traceable to the following:

1. Quackenbush preliminary holes are being satisfactorily produced to specification tolerance as starting holes for subsequent cold-working.

2. Quackenbush air powered drill motor driving a piloted tip reamer produces very good final holes per 0.5005".0.5025" tolerance criterion.

3. The affect of good tooling is evident in the shape and quality of these holes.

4. Periodic inspections prior to the final hole inspection as directed by the Log Planning is a significant factor in determining specification compliance and final hole quality.

III. CHARACTERISTICS:

A. Hole Size: 1416 data measurements were accrued from the nineteen (19) holes comprising this set. Reference Executive Summary by Data Lot discloses an arithmetical average of 0.501438" which is very good for the set and is reflected in the quality of these very deep holes whose tolerance spread is only 0.0020" total.

Slight chip load build up in the process of reaming exceptionally deep holes results in some tapering (bellmouthing) and bulging (barrelling) which are the only geometrical features departing from ideal cylindricity in the holes.

All of the specimens conform to the tolerance criterion established by Engineering.

1. Reference Individual Hole Computer Printouts for holes identified Hole #1, 2 and #3.

   In this set of holes, the profile established by eighty-eight (88) and/or seventy-six (76) measurements per hole via 0^o, 45^o, 90^o and 135^o axes discloses a double taper and/or bellmouth characteristic. The narrowest point of this feature exists at the interface vicinity of the faying surfaces of the spar cap to heavy fitting, at the ninth (9th) plane of measurements along each axis profile presentation.

   Center-seeking at the start of reaming is assessed the most probable cause for the extremely slight bellmouth at the top of the hole and the uniformity with which it diminishes as depth in hole is achieved.

   The gradual increase (barrelling) after passing through the spar cap to fitting interface is suggestive of minor chip load build up most probably the result of the great hole depth. In either case, the magnitude and progression is small, relatively uniform and does not exceed the Engineering tolerance allowable.

2. Reference Individual Hole Computer Printouts for holes identified Hole #12, 13, 14 and #15. In this set of holes (S/N 215 Center Wing R.H. Side) the profile established by ninety-two (92) and/or seventy-two (72) measurements per hole discloses slightly different profiles from those of Item III.A.1.

In the above holes of this set, the bellmouth feature is missing, but the gradual chip load build up and subsequent minute hole profile enlargement is present.

The range of measurements creating the profile is very slight as follows:

Hole #	Range	Hole #	Range
12	0.000693"	14	0.000966"
13	0.001129"	15	0.000417"

Cause for the minor profile variation has been discussed at item III.A.1. The above holes are assessed good specimens and meet all Engineering criterion.

3. Reference Individual Hole Computer Printouts for holes identified Hole #4, 5, 6 and #7. In this series of holes (S/N 214 Center Wing L.H. Side) the bellmouth feature is predominant in Hole #4 and #7 and the chip load enlargement at Holes #5 and #6. The range variation is very slight as follows:

Hole #	Range	Hole #	Range
4	0.001164"	6	0.000662"
5	0.001031"	7	0.000629"

All measurements and features of these holes meet the Engineering criterion.

4. Reference Individual Hole Computer Printouts for holes identified Hole #8, 9, 10 and #11. This series of holes (S/N 214 Center Wing R.H. Side) are the best specimens of this set. Their range of measurements are as follows:

Hole #	Range	Hole #	Range
8	0.000343"	10	0.000500"
9	0.000655"	11	0.000491"

The bellmouth and/or taper and chip load enlargement is extremely minute and are not considered a detriment to the overall quality of these holes.

5. Holes #16, 17, 18 and #19 (S/N 213 Center Wing L.H. Side) are generally a repeat of the features and related causes expressed in the narrative and rationale per item III.A.1.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #16 and discloses a value of 0.000828" on the 45° - 135° axes at plane #23. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the irregular reamer breakout spike in this hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printouts. All holes are extremely good on ovality measurements, (predominantly less than 0.0005"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Reference Section I.B. of this report. Heavy custom tooling compensates for the angularity variation from the skin contour to the pylon fitting and the inside support fitting. These holes are normal to the pylon and support fitting bearing surfaces of the pylon studs.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Several holes of this set exhibit a shallow barrelling feature. Refer to narrative at paragraph III.A.1 thru III.A.5 for details.

F. Bellmouthing: Several holes of this set exhibit a very slight bellmouth feature at the start vicinity of reaming. Refer to narrative at paragraph III.A.1 thru III.A.5 for details.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This series of specimens exhibited a very good interior wall texture.

The holes were inspected via Sight Pipe at 3X magnification. There were no rifling, chatter marks nor vertical scoring in this set of holes.

H. Burrs: Deburring was satisfactorily accomplished per the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of 100 AA or better. Optical Surface comparator was used in inspection and the sidewalls were smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 47 *

HOLE SIZE: 0.250"/0.253"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Longeron Installation, Fuselage Mid-Section.

The structure is a multi-layered stack approximately 1.00"thick in the areas to be surveyed. The subject hole is sized by Engineering at 0.250"/0.253" for installation of XL4(GB511D) HiLok Bolts.

B.

	Holes 1 through 25
Drill	0.2344" diameter, #P118891-1
Reamer:	0.2502" diameter, #P118892-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	HE-2 @ 10:1 Water Mix Spray mist

	Holes 26 through 29
Drill:	0.2344" diameter, #P-195240 coredrill
Reamer:	0.2500" diameter, #P-118894-1
Motor:	QDP-15APB, 3/8" Jacobs Chuck
Coolant:	HE-2 @ 10:1 Water Mix Spray Mix

Note: Inspection utilizes plug "Go" and blade "No-Go" gaging method.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air power reamer, mechanical Quackenbush, air powered drill & accessory tooling.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized heavy drill plates, pinned and clamped to the assembly fixture to facilitate locking on the Quackenbush, air driven drill power head. Hand brush-on and Squeeze Bottle HE-2 coolant was used as drill/reamer lubricant. Holes were drilled by Quackenbush to a preliminary size of 0.2344" and followed by Quackenbush, air driven drill motor and 0.2500"/0.2502" piloted tip reamer to achieve the final hole. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.250523" for the set of twenty-nine (29) holes. This value is an ideal feature since it resides at the low-point vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces preliminary holes at assembly to 0.2344" size.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering using a 0.2502" reamer for Holes #1 through #25 and a 0.2500" reamer for Holes #26 through #29.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug and blade gages are employed for "Go"/"No-Go" inspection.

III. CHARACTERISTICS:

A. Hole Size: 1160 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.250523", well below the 0.2530" high limit per established Engineering Criterion. This is an exceptional series of holes on size and other geometric characteristics disclosed via computer printout and profiles.

Reference Computer Individual Hole Printout discloses an excellent range distribution of hole measurements considering material thicknesses within the stack resulting in a (1.00") depth for the drilled/reamed holes.

1. The spread of measurements taken at forty (40) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000431"	16	0.000629"
2	0.000379"	17	0.000259"
3	0.000784"	18	0.000284"
4	0.000517"	19	0.000457"
5	0.000293"	20	0.000267"
6	0.000181"	21	0.000181"
7	0.000414"	22	0.000172"
8	0.000595"	23	0.000293"
9	0.000388"	24	0.000345"
10	0.000267"	25	0.000267"
11	0.000276"	26	0.000328"
12	0.000734"	27	0.000164"
13	0.000466"	28	0.000638"
14	0.001336"	29	0.000250"
15	0.000284"		

Note: Only one (1) hole, identified Hole #14 exhibited a range of measurements that exceeded 0.001" over the forty (40) measurements per hole.

2. This set is an extraordinarily good series of holes. Thirteen (13) specimens, identified Hole #5, #6, #10, #11, #15, #17, #18, #20, #21, #22, #23, #25 and #27 exhibit a difference of less than 0.0003" total in their forty (40) measurements per individual hole. Increasing the value to less than 0.0005" incorporates additional holes identified Hole #1,#3,#7,#9,#13,#19,#24,#26 and #29 and arrives at 76% of the set featuring a variation below 0.0005". Considering the hole depth in excess of 1.00", the measurement results are excellent. The attributes of stiff tooling, vertical positioning of the powerhead with tight lock-up and sharp drill/reamer cutting tools are apparent in the quality of the finished holes. Operator skill, attitude and pride were demonstrated to be optimum levels by personnel manning this work station.

3. Hole #14 exhibits the greatest range in measurement spread at 0.001336". This hole is a specimen from the group in the all aluminum material stack-up. Chip build-up inside the hole resulting from coolant starvation induced heat build-up and hole enlargement. Stalls of the drill/reaming drive units were observed on several holes of the right hand assembly. Chip clogging was extremely heavy and had to be manually cleared. Spot checks revealed the holes to be larger than others in the pattern where drilling was not impaired by stalls. Hole #14, the largest hole, did not exceed the Engineering tolerance criterion.

4. Reference Individual Computer Profile Printout. Holes #3,#8 and #16 reveal profiles of similar characteristics to Hole #14. The range variation for these holes at 0.000784", 0.000595" and 0.000629" suggest the cause for hole shape to be the same as Hole #14.

5. Individual Hole Histograms disclose a Normal Gausian Distribution on measurement population, providing conclusive evidence of process, tooling and personnel performing in perfect harmony.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #12 and recorded at 0.000388" at Level #9 on the 0^{o}-90^{o} axes. This value is negligible and does not cause quality degradation of the hole.

Ovality was not a cause for concern on this lot. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. This series of holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were verified to be normal (90^{o}) to the longitudinal axis of the holes with regard to the drilled/reamed longeron structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: None existent as evidenced by profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There were only slight perceptible rifling traces on the hole sidewalls when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "100 AA". Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 48 *

HOLE SIZE: 0.312"/0.315"

I. OVERVIEW:

A. This set of production holes features Quackenbush drilling and reaming of the Vertical Stabilizer Box Assembly.

The structure is a graphite epoxy skin, liquid shim, and aluminum closing rib. All holes are sized by Engineering at 0.312"/0.315" for installation of ACN10 (MS21141) Blind Protruding Head High Strength Fasteners.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production was Quackenbush, air powered drilling and follow-up Quackenbush reaming of the holes to final size. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot.
This set discloses a measurement distribution whose arithmetical average is 0.314776". This is an exceptionally high value brought about most probably by fibrous material choking the chip flutes and resulted in two-thirds of the holes of this set exceeding the high limit of the Engineering tolerance. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling for production of preliminary holes at assembly.

3. Quackenbush, air powered drill, driving a piloted reamer achieves hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

* DRILL METHOD CODING: Q-2 = Quackenbush - Air Power reamer, mechanical Quackenbush, air powered drill and accessory tooling.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. CHARACTERISTICS:

A. Hole Size: 580 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.314776". This average is exceptionally high and is brought about by the fact that most of the holes in this set are tapered and approach and/or exceed the high limit tolerance of 0.315" established by Engineering.

1. The basic size of this set of holes is extraordinarily large as compared to other sets in an all aluminum structure. The graphite epoxy, drilled dry, is strongly suspect of flute clogging and causing excessive chip build-up enlargement of the holes.
Refer to Individual Hole Computer Printouts. Twenty (20) holes of the sample size of twenty-nine (29) holes reveal an arithmetical average in excess of the 0.315" high limit established by Engineering. Refer to the Axes (0°-45°-90°-135°) series of measurements for hole growth and profile of their enlargement tapers. The Individual Hole Arithmetical Averages for these holes are as follows:

Hole #	Average	Hole #	Average
1	0.315234"	16	0.315412"
2	0.315093"	17	0.315354"
3	0.314595"	18	0.315035"
4	0.315077"	19	0.314941"
5	0.314868"	20	0.314775"
6	0.314314"	21	0.314144"
7	0.314784"	22	0.315122"
8	0.314735"	23	0.314422"
9	0.315137"	24	0.315113"
10	0.315249"	25	0.314059"
11	0.314746"	26	0.313871"
12	0.315090"	27	0.314432"
13	0.315303"	28	0.313848"
14	0.314593"	29	0.313917"
15	0.315251"		

Note: It is important to note that the shape of the holes on this set is more significant than size. Ordinary "Go"/"No-Go" Gaging <u>would not</u> in most cases reveal the taper existing in the holes since the feature is predominantly on the bottom of the holes.

2. Reference Individual Hole Histograms and Executive Summary Lot Histogram.
   Both Histograms disclose data population near and exceeding the tolerance high limit. The data and profiles of these holes suggest an evaluation study to improve the basic shape of holes in the graphite epoxy structure if all tolerances noted by engineering are required.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #3 and recorded at 0.002620" at Level #3 on the 45°-135° axes. Ovality was caused by a bubble in the cured liquid shim. A glazed shrunken area was noted inside the hole via 3X magnification Sight Pipe inspection. The glaze was a portion of a bubble in the liquid shim material which was not perceptible to the naked eye.

Ovality generally was not a concern for this set. All of the ovality measurements were within the tolerance criterion established by Engineering.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90°) to the longitudinal axis of the holes and skin mold line.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent per profile analyses.

F. Bellmouthing: This is the most predominant geometric feature apparent on this set of holes. The characteristic has been addressed per narrative at item III.A and III.A.1.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle shredding in the graphite epoxy perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "100 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except for occasional shredding in the graphite epoxy and a few very slight bubbles in the liquid shim material.

DRILL METHOD Q-2

RANKING NUMBER 49 *

HOLE SIZE 0.3745"/0.3755"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Cargo Door Latches. The structure is titanium approximately .300" thick at the surface to be drilled and reamed. The hole being inspected is sized at 0.3745"/0.3755" by Engineering.

Hole survey measurements were obtained using a "thru-hole" air probe coupled to an Automated Computer System for data storage and recovery. Only two (2) measurement planes (8 measurements per hole) were obtained owing to geometric restrictions on the parts being checked.

II. SUMMARY:

A. Only fourteen (14) holes were inspected in this set owing to hardware availability and the fact that the material was titanium and Project 1000 is primarily concerned with aluminum aircraft structure. This hardware was available on the production line on a non-interference basis; therefore, inspection was performed by "thru-hole airprobe" to broaden our base of knowledge on production drilling/reaming.

B. Tooling appears to impart a cause for concern on this set of holes. The method of production employed Quackenbush drilling/reaming with the drill head in horizontal position. Only three (3) holes in the series met the tolerance criterion established by Engineering. The eleven (11) remaining exceeded the tolerance high limit by varying degrees as reported in paragraph III.A. Other characteristics related to the hole configurations are also hereinafter discussed.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom fixture design for interface control/interchangeability reliability and Quackenbush drill adaptation.

2. Quackenbush drill/reaming method and accessories used for hole production.

3. Planning is excellent for inspection traceability on holes.

4. Special tooling required for production of these holes are specified and use directed per planning.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air power reamer, mechanical Quackenbush drill/reaming w/drill head in horizontal position.

5. Morale among production personnel is high, but evidently unaware of the tooling impact on hole quality.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary by Data Lot". 112 measurements were accrued for this series of fourteen (14) holes. The arithmetical average for the set is 0.375530". Hole finish at "63 AA" is excellent. Eleven (11) holes of the set exhibit out of tolerance measurements as evidenced by their individual profiles and are discussed hereinafter.

b. Holes #1, #3 and #6 meet the size criterion established per Engineering. However they exhibit a common characteristic of "bellmouthing" and/or "taper" at their exit plane of measurements which is inherent in all of the holes of this set. Chip load is suspected of causing this condition since it occurs at all axes of measurement and at the exit plane of the hole. The drill/reamer exiting the hole shortly after the second measurement plane precludes hole enlargement at its start plane of drilling/reaming. Side-loading by the operator and/or weight moment arm of horizontally mounted Quackenbush drill head is discounted on this phenomenon because it is apparent in all axes of measurement.

c. Holes #2, #4 and #8 are oversize at adjacent axes resulting from the influence drill head side-loads induced via operator handling while drill is in motion. Hole #2 per Individual Profile Printout yields 0^{o} and 45^{o} axes affected; Hole #4 discloses 0^{o} and 135^{o} axes and Hole #8 is affected at axes 0^{o}-45^{o} and 135^{o}.

d. Holes #5 and #11 are oversize at all four (4) axes at the exit plane of the holes. Chip load, but to greater extent, is suspected as cause for the oversize condition. The drill/reamer exiting the hole shortly after plane #2 relieves the condition and precludes hole enlargement at the start plane.

e. Six (6) holes, identified Hole #7, #9, #10, #12, #13 and #15 were oversize the entire length and at all axes. Considering the material to be 17-4 PH Stainless Steel of substantial thickness and absence of automatic coolant feed, heat and cutter edge dulling are suspect for a completely oversized hole. The hole sequence (taken directly

from the identifier placed on the parts by the operator) adds creditability to "dulling" as cause of the oversize problem.

B. Ovality: Maximum record ovality within the set was 0.000388" at hole #8. Individual holes within this set (8 measurements per hole) ranged to as low as 0.000009". Ovality was not a concern on these holes. All holes including the oversize holes are within the allowable criteron established by Engineering.

C. Perpendicularity: All holes within this set were absolutely normal to the longitudinal axis of the hole with regard to its spotfaced machining (interface surface) of the actuator to the torque tube. Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device off of the fixture.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses

F. Bellmouthing: Evident on all holes of the set at the exit plane of the holes as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. Holes were visually inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 50 *

HOLE SIZE 0.2495"/0.2515"

I. OVERVIEW:

A. This set of production holes features double margin piloted tip drilling of the Cargo Door Hinge and Jamb Structure. The structure is a stainless steel pre-drilled hinge, aluminum jamb and frame gusset stack up. The stack up of structure is approximately .500" thick and incorporates a gray colored "rubbery" textured sealant material between faying surfaces at all layup interfaces. The subject hole is sized by Engineering at 0.2495"/0.2515" for Huck-Bolt Fastener installations.

Hole survey measurements were obtained using a "thru-hole" air probe coupled to an Automated Computer System for data storage and recovery.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated predrilled, installed hinge to ensure basic hole locations and interchangeability. A hand-held, air powered, drill motor driving a double-margin piloted tip drill was employed to obtain the preliminary hole using the steel hinge as a drill guide. A hand-held, air powered, drill motor driving a DJ-380 (0.2495) special piloted reamer was used to obtain a finalized hole per Engineering requirements.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.250750", a desirable feature since the low and high limit criterion is 0.2495"/0.2515" respectively as established per Engineering. Ten (10) holes reveal out of tolerance measurements. These holes along with other specific characteristics relating to these holes are discussed in detail at paragraph III.

* DRILL METHOD CODING: H-2 - Hand-held Drill and Reamer Hand-held, air power drill. Hand-held air power drill w/special reamer.

II. (Continued)

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom major assembly fixturing ensures structure alignment and positioning reliability.

2. Hand-held, air powered drill method and accessories are adequate to the production of good quality preliminary holes in preparation for final reaming.'

3. Hand-held, air powered drill motor driving a special reamer produces good quality final holes.

4. The installed structural stainless steel hinge was used as the "lead-in" for the drilling and reaming operations. Engagement length considered too short is suggested as cause for some degradation of hole quality. Ref. paragraph III.

5. Planning is adequate to direct manufacturing and inspection operational requirements. Close tolerance holes are inspected by sampling per planning direction.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary by Data Lot". 696 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.250750" and hole finish at "100 AA" or better is excellent. Ten (10) holes of the set exhibit out of tolerance measurements as evidenced by their individual profiles and are discussed hereinafter.

b. Holes #9 and #13 reveal one "lead-in" drill reamer spur at 0.251509". Both were at the entrance plane of the drill and at the 45^{o} (hole #9) and 90^{o} (hole #13) axes respectively. Both were regarded as no defect per analysis and are not included in the ten count referenced in "a" above.

III. A. (Continued)

c. Holes #2, #3 and #25 disclose either a "lead-in grab scar" or "bread-out eccentric chip scar". In all cases, the oversize is extremely small, very shallow and is limited to one plane of measurements. Per analysis, all were considered too insignificant to discount the quality of the affected hole.

d. Holes #4, #23, #24 and #27 disclose oversize dimensions which occur at two adjacent axes and at successive plane levels in the holes. Hole #4 at plane levels #1 and #3, whereas the remainder occur at plane levels #5 and #6 in the holes. The phenomenon is suggestive of operator instability since it is a characteristic associated with shallow depth of hinge lead-in guide and operator instability on the drill head. Operator side-loads and drill "break-out" also affect the hole at its exit plane in the same manner.

e. Holes #6, #14 and #29 were the most seriously affected oversize holes of this set. In each case these holes per Individual Profile Printout disclose excessive side-loading running nearly the full depth of the hole and at adjacent axes which result in 180^{o} of the hole sidewall. At Hole #6 the 45^{o} and 90^{o} axes are affected; on Holes #14 and #29 the 0^{o} and 135^{o} axes are affected. The operator instability on either the drilling or reaming operations conceivably resulted in the ovality and oversize for the subject holes.

III. A. (Continued)

f. The "Executive Summary Histogram" for this set discloses full utilization of the entire tolerance spread. The out of tolerance conditions are explained in items b through e above. The tendency toward the high limit of the tolerance is brought about by the "bellmouth" or "taper" exhibited by the examples described in these items while the low limit band of the tolerance is representative of the basic hole.

B. Ovality:

a. The greatest ovality of the set occurred at Hole #14, Level #4 and was recorded at 0.001991". The consequence of hole ovality is described in Item III.A.e. above.

DRILL METHOD Q1

RANKING NUMBER 51 *

HOLE SIZE 0.375"/0.379"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Rear Spar. The assembly is of riveted sandwich construction consisting of a forward cap, web and aft cap. The overall thickness of the spar is 1.000" thick at its top and bottom inboard end. The first seven holes sized at 0.375"+.004"/-.000" by Engineering, are the subject holes for measurement survey. A "thru-hole" air probe was used for all size measurements on these holes.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated custom fixturing for hole location. Holes were drilled by a custom fixtured, track mounted vertical Lazy-Arm Farnham Drill. Drill plates accommodated the lead-in for Farnham drilling. Drilling was performed with a 0.300"/0.374" piloted, deep fluted, double margin drill. Reaming was accomplished out of the fixture, with hand-held air powered drill motor and a piloted reamer. The physical part (spar) was used as the "steering-guide" for reaming the part to its final hole size.

B. All of the holes are well within the tolerance spread established by Engineering and average overall at the midpoint range of the tolerance. Reference to the "Executive Summary by Data Lot" reveals the average hole size to be 0.377154", a desirable feature since the high and low limit criterion is 0.375000"/0.379000" respectively. The specific characteristics for these holes are discussed in detail at paragraph III.

* DRILL METHOD CODING: Q-1 = Quackenbush - Hand-held Air power reamer.
Vertical lazy-arm Farnham drill w/hand-held, air powered reaming out of fixture.

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixture ensures interchangeability and location reliability.

2. Lazy Arm Farnham Drill, air powered, track mounted and integral to the fixture used for drilling produced excellent basic holes sized at 0.370"/0.374".

3. Hand-held air powered drill motor, piloted reamer for final hole reaming to 0.375"/0.379".

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: a. Reference "Executive Summary" for this set. 1623 measurements were accrued for this series of holes. The Arithmetical Average" for the set is 0.377154".

b. All twenty-nine (29) holes were within the Engineering tolerance limits. Only one (1) measurement of the 1623 total disclosed an out of tolerance condition. It occurred at Hole #10, Level #5. Its value was detected and recorded at 0.379379"; oversize at 0.000379". This phenomenon is analyzed to be a chip scar resulting from the break-off of the spar cap chip, or the start of the web chip exiting the hole. The interface of the spar cap to web occurs at the next deeper level in the hole. The incident is extremely insignificant.

NOTE: Refer to the "Executive Summary Histogram", the "Individual Hole Histograms" and the Individual Hole Profile Analyses. The following is evident and will be discussed in detail:

1. These holes are predominantly larger at the top (first levels of measurements) and smallest (last levels of measurements) at the exit plane of the reamer.

2. The Individual Histograms reveal measurement population from the vicinity of 0.376000" to slightly beyond 0.378000".

3. The Summary Histogram reveals an aggregate population of data elements congested about the 0.376000 area; then, following a break in data elements, picking up again in the 0.378000/0.379000 vicinity.

4. The Individual Hole Profiles reveal predominantly larger top half holes in the spar laminated structure than exist at the bottom half.

The four (4) characteristics above suggest the following conclusions may be drawn from these clues:

a. The hand reaming operation is the primary cause of the hole enlargement condition since the physical spar assembly drilled holes were used as the reamer guide. See Condition #1 above and paragraph II.A.

b. The saving grace for this series of holes remaining within specification lies in the fact that the Engineering tolerance spread is 0.004". Subtle side loads induced by the operator during his reaming created both the enlargement and ovality characteristics. The deeper into the hole the reamer penetrated, the more stability it achieved, thus resulting in the lower extremity being the smallest of hole measurements. Items 1 and 2 above relate to these circumstances.

c. The summary Histogram contribution discloses a cluster representative of the lower portion of the holes (0.376000" vicinity) and the migration owing to operator instability results in the high limit measurements (0.378000"/0.379000").

d. The Hole Profiles reveal characteristics associated to the enlargement and ovality measurements within the holes.

e. More stable tooling is suggested as a corrective action to eliminate the measurement and geometric characteristics presently existing in this structure.

B. Ovality: All of the holes of this set tend on ovality to congregate in the range of 0.001" to 0.002" and are consistent with the basic enlargement of the holes. Cause is hand reaming as previously stated. The maximum ovality for the set is 0.002595" at Hole #10. The ovality conditions all fall within the allowable tolerance range established by Engineering.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined surface of the fittings. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device. The basic perpendicularity integrity was established by the fixture drilling of the 0.370"/0.374" basic hole.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: Occasional as indicated by profile analyses.

F. Bellmouthing: Generally evident as indicated by profile analyses. This characteristic was precipitated as a result of hand reaming and operator instability.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only

an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through stacked arrangement of forward spar cap, web and aft spar cap was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 52 *

HOLE SIZE: 0.3080"/0.3130"

I. OVERVIEW:

A. This set of production holes features drilling of the Flap Fitting Structure, Center Flap. The structure is an all aluminum stack whose approximate thickness in the area to be surveyed is 0.750". The subject hole is sized by Engineering at 0.3080"/0.3130" for installation of Hi-Lok bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. All holes except three (3), identified Hole #2, #10 and #20 of the set, are in complete compliance with all Engineering criterion. Measurement data was accumulated at forty (40) locations within each hole via "thru-hole" air probe. Holes #2, #10 and #20 will be discussed in detail at paragraph III. along with other geometric features of the holes.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.310477" for the set of twenty-nine (29) holes. This value is a very good feature since it resides at the mid-point of the Engineering tolerance range.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces very good preliminary holes at assembly.

* DRILL METHOD CODING: Q-1 = Quackenbush - Hand-held air power reamer
Quackenbush air powered drill and accessory tooling.

II. C. (Continued)

3. Hand-held, air powered drill driving a piloted reamer achieves final hole size per Engineering.

4. A Tool Set-Up Station is maintained in the vicinity of the work area. Quackenbush drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 1160 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.310477" as evidenced per the Executive Summary by Data Lot. Holes #2, #10 and #20 exhibited only minor tolerance violation as follows:

1. Hole #2. Only one (1) measurement of the forty (40) data elements for this hole is oversize. The measurement is 0.313284" and occurs at the exit plane of the hole on its 90^{o} axis reference. This flaw is a "break-out" spur and is of such meager magnitude it has been discounted as a detriment to the quality of the hole. Irregular break-out load is suggested as cause for this spike. The plane level directly above the spur and on the same reference axis (90^{o}) provides a clue (0.313026") to the size in length limit (1/8") of the flaw, running perpendicular to the exit plane. Operator instability on the hand reaming operation no doubt induced side loads (as evidenced in the Computer Profile) and resulted in irregular break-out spike.

III. A. (Continued)

2. Hole #10 is very similar to Hole #2 and for the same reasons. The spikes on Hole #10 occur at the exit plane of the hole, at the 0^{o}, 45^{o}, and 90^{o} reference axes. The magnitude of the oversize condition is related by values of 0.313078", 0.313388" and 0.313259" respectively with regard to a high limit tolerance of 0.313000". This flaw occurring at the extreme end of the hole has been discounted as a detriment to hole quality owing to its location and size.

3. Hole #20 exhibits its oversize at the start plane of the hole. The depth into the hole is limited to one (1) plane level; thus, length of the oversize with regard to the hole is only 0.100". The total length of the hole is 0.75". Operator instability on reaming is again considered the cause of the flaw. Side load affect with its accompanying bellmouth and/or taper is in evidence in all three (3) of the aforementioned holes.

4. Five (5) holes are nearly perfect specimens. Computer Individual Printout discloses the total range of <u>forty (40) measurements</u> per hole to be <u>less than</u> 0.000300". These holes and range of measurements are as follows:

Hole #	Range
5	0.000198"
6	0.000250"
7	0.000284"
13	0.000297"
14	0.000284"

III. A. 4. (Continued)

The above holes are excellent and outstanding considering the hand reaming operation performed to achieve their final size.

5. Hole #15 is in the same status of perfection as those of item III. A. 4. The last plane of measurements in this hole are spiked due to the air-probe sensing the chamfer created by deburring the end of the hole. Discounting this plane of measurements, the range for Hole #15 is 0.000293", derived as follows:

Plane #8 of the 0^{o} axis = 0.310431"
Plane #5 of the 90^{o} axis = 0.310138"
0.000293"

6. Eleven (11) holes are very closely related to those of item III.A.4; however, their Individual Profiles reveal the affect of very subtle side load and/or chip build up deep inside the hole resulting in slight bellmouth and/or taper enlargement. The holes and their specific range of measurements are as follows:

Hole #	Range
4	0.000422"
8	0.000405"
9	0.000345"
11	0.000388"
17	0.000353"
18	0.000388"
21	0.000392"
22	0.000340"
24	0.000353"
27	0.000483"
28	0.000362"

III. A. (Continued)

7. The remainder of the holes are Hole #1, #3, #12, #19, #23, #25, #26, and #29. The holes are very good holes on size also, disfigured slightly by entrance or exit area bellmouthing and some extremely small side load enlargement. At worst case, the magnitude of enlargement is less than 0.0009".

8. Reference Executive Summary Histogram. The measurement population for this set is all centered about the 0.310000"/0.311000" zone of the tolerance established by Engineering at 0.308000"/0.313000". The population is typical of a Normal Gausian Distribution typifying a condition of tools, process and personnel in harmonious operation.

B. Ovality:

Maximum recorded ovality within the set occurred at Hole #20 and discloses a value of 0.001681" at plane level #10 on the 0^{o}-90^{o} axes. Hole #20 Individual Profile discloses a relatively straight taper enlargement from plane #2 through break-out at plane #10. This condition is suggestive of operator instability during the hand reaming operation, The ovality feature of Hole #20 did not exceed the Engineering tolerance.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

III. (Continued)

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Nonexistent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated per item III.A.6. Refer also to item III.A.7. The referenced holes of this group exhibit the same condition of their entrance plane of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and fitting was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 53*

HOLE SIZE 0.2500"/0.2540"

I. OVERVIEW:

A. This set of production holes features drilling of a structure, approximately 0.625" thick. This is an aluminum stack-up of three (3) laminates (-001 machined fitting, web and -002 machined fitting). The subject hole is sized by Engineering at 0.2500"/ 0.2540" for HiLok fastener installation, Type II, per STP 2006.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized a pilot drilled -001 machined fitting to assure basic hole location. These holes were drilled on assembly by hand-held, air powered drill motor for all drilling operations. Reaming was not planned nor performed to obtain the final hole sizing. Several drilling operations were performed to arrive at the final hole size. Drill stalling was an infrequent occurrence on this series of holes, and most probably was a product of less material removal between the drill steps leading up to final sizing of the structure being drilled. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. These holes disclose a measurement distribution whose arithmetical average is 0.250669" for the set of twenty-nine (29) holes. This attribute is ideal since it is at the extreme low limit of the 0.2500"/0.2540" established Engineering Criterion. All twenty-nine (29) holes of this set are well within the tolerance. Details on the geometric features of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Hand-held, air powered drill method and accessories produces good basic holes. Accessory tooling was a drill block, secured by cleco clamping in a preceding hole to stabilize the tooling against "roll-over" during drilling. Drill block is similar to spacematic drill locating.

* DRILL METHOD CODING: H-1 = Hand-held Drill, No reaming.

Pilot drilled -001 machined fitting. Hand-held, air powered drill. No reaming.

3. Reaming was not planned nor employed to obtain the final hole size.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: These are excellent holes. 1044 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set at 0.250669" is an ideal attribute considering the 0.2500"/ 0.2540" established Engineering Criterion. This series of holes additionally is exceptionally good on "roundness." In several cases only 0.0001"/0.0003" separates the 36 measurements made in <u>each hole</u>.

a. Six (6) holes, identified Hole #3, #4, #5, #19, #21 and #22 are nearly perfect. On nine (9) planes of of measurements, thirty-six (36) recordings per hole, <u>the total range from largest to smallest</u> recordings are as follows:

Hole #3. . . . . 0.000310"
Hole #4. . . . . 0.000353"
Hole #5. . . . . 0.000293"
Hole #19 . . . . 0.000345"
Hole #21 . . . . 0.000293"
Hole #22 . . . . 0.000284"

b. Five (5) holes, identified Hole #2, #7, #8, #10 and #20 are very similar to the holes described above. An extremely subtle bellmouth taper at the exit end of the drilling caused the range of measurements to increase slightly.

c. Hole #1 disclosed the highest reading of the entire set at 0.253431" which occurred at Plane #8, on its 45° axis of orientation. Referencé to the Individual Profile Printout reveals a side loading condition along the 45° and 90° axes brought about by operator drilling instability.

d. Holes #11 and #17 are similar to Hole #1. Side-loading along the same axes and for the same reason exists on Hole #17. Hole #11 exhibits the condition predominantly along its 0° and 135° axes.

e. The Individual Histograms disclose a normal Gausian Distribution except in cases where side loading and operator instability induced variations. Collectively, the variations are apparent on the Executive Summary Histogram for this set. Generally, the set is very good example of process, tooling and operator personnel functioning in harmony.

B. Ovality: Hole #18 revealed a maximum ovality within the set and was recorded at a magnitude of 0.002448" at Level #9 on the 45°-135° axes. Ovality was induced by operator side loads as described in item III. A. c.

Ovality was not a cause for concern on this set of holes. Holes #5 and #19 recorded values as low as 0.000052"/0.000086" and 0.000060"/0.000078" for this feature. There are no ovality conditions in this set which exceed the Engineering Criterion.

C. Perpendicularity: The flange geometry of the machined fittings would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None evident as indicated by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by Holes #23, #24, #28 and #29. Various other holes of this set exhibit the same condition at either their entrance or exit planes of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 54 *

HOLE SIZE: 0.250"/0.254"

I. OVERVIEW:

A. This set of production holes features Quackenbush drilling and reaming of the Outer Wing Assembly.

The structure is a graphite epoxy skin, liquid shim, and aluminum substructure. The subject holes are located along the inboard, root end, of the wing between the front and rear spars. The holes are sized by Engineering at 0.250"/0.254" for installation of NAS 6204 Bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available from one (1) Left Hand and one (1) Right Hand Wing. The method of production was Quackenbush, air powered drilling of preliminary holes followed by Quackenbush reaming of the holes to final Engineering size. Inspection measurements were obtained via "thru-hole" air probe coupled to data storing HP Programmable Calculator.

B. Reference Executive Summary by Data Lot.
This set discloses a measurement distribution whose arithmetical average is 0.253522". This is an exceptionally high value brought about most probably by fibrous material choking the chip flutes and chip load resulting in enlargement and taper in these holes at either their entrance or exit plane vicinities. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling for production of preliminary holes at assembly.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power reamer, Mechanical Quackenbush, air powered drill and accessory tooling.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. CHARACTERISTICS:

A. Hole Size: 580 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.253522". This average is exceptionally high and brought about by the fact that most of the holes in this set are tapered and approach and/or exceed the high limit tolerance of 0.254" established by Engineering.

1. The basic size of this set of holes is extraordinarily large as compared to other sets that are all aluminum. The graphite epoxy, dry drilled and reamed, is strongly suspect of flute clogging and resulting in excessive chip build-up enlargement of the holes.
Refer to Individual Hole Computer Printouts.
Eight (8) holes of twenty-nine (29) holes reveal oversize conditions to the high limit 0.254" established per Engineering. Refer to the Axes (0°-45°-90°-135°) series of measurements for hole growth and profile of their enlargement tapers. The Individual Hole Arithmetical Averages for these holes are as follows:

Hole #	Average	Hole #	Average
1	0.253351"	16	0.252400"
2	0.253452"	17	0.253231"
3	0.253262"	18	0.255289"
4	0.253348"	19	0.252910"
5	0.253128"	20	0.252282"
6	0.253903"	21	0.253687"
7	0.253521"	22	0.253932"
8	0.253408"	23	0.253436"
9	0.253163"	24	0.254105"
10	0.253465"	25	0.253804"
11	0.253670"	26	0.253870"
12	0.253526"	27	0.253343"
13	0.253333"	28	0.253462"
14	0.253327"	29	0.253835"
15	0.254709"		

Note: Reference to Individual Hole Computer Printouts disclose a fairly equal distribution of entrance plane to exit plane taper enlargement. Ordinarily, via "Go"/"No-Go" Gaging, holes #15,#18, and #24 are the only specimens which would be picked up as oversize owing to the fact that they are generally

oversize at all axes and for considerable, if not full length of engagement. The tapers existing on Holes #11 and #26 would not be detected because they are <u>on the bottom side</u> and are only very slightly oversize.

The tapers on the entrance vicinities (top side of the skin (Holes #6,#11,#22 and #29) are slight and shallow and most probably would be accepted per normal inspection rationale of the "no-go" gage barely entering the hole and only at the top.

2. Reference Individual Hole Histograms and Executive Summary Lot #5 Histogram.
   Both Histogram records reveal data populations near and/or exceeding the tolerance high limit. The data and profiles of this set suggest an evaluation study to improve the basic shape of the holes in the graphite epoxy structure.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #4 and recorded at 0.001038" at Level #4 on the 45^{o}-135^{o} axes. Ovality was caused by the "spike" in the data representative of a bubble in the liquid shim material inside the hole. A glazed concave area was invisible via sight pipe inspection at 3X magnification. Ovality generally was <u>not</u> a concern for these holes. All of the ovality measurements, except Hole #4, were <u>below</u> 0.001" in magnitude. None of the holes exceeded the Engineering tolerance on ovality.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90^{o}) to the longitudinal axis of the holes and skin moldline. Inspection of installed fasteners in other assemblies also revealed no perceptible head gaps.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None =existent per profile analyses.

F. Bellmouthing: This is the most predominant geometric feature apparent on this set of holes. The characteristic has been addressed per narrative at item III.A. and III.A.1.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle shredding in the graphite epoxy perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "100 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except for occasional shredding in the graphite epoxy and several very slight bubbles in the liquid shim material.

DRILL METHOD S-2

RANKING NUMBER 55 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling, reaming, cold working and final reaming of the Rear Spar Installation, Upper Surface. The structure is an all aluminum stack consisting of the rear spar flange and the upper skin panel. The approximate thickness in the area to be surveyed is 0.625". The subject hole is sized by Engineering at 0.2460".0.2500" for installation of Hi-Lok flush head bolts following the final reaming after cold working of the holes.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized Spacematic drilling of preliminary holes to 15/64" diameter; hand reaming to 0.235"/0.238" in preparation for cold working; cold working by means of split sleeve expansion of the holes; then, final hand reaming to 0.2460"/ 0.2500".

Measurement data was accumulated at thirty-two (32) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.248657" for the set of twenty-nine (29) holes. A single characteristic of side load enlargement induced via the hand reaming operation had a significant affect on the holes individually and also on the above noted set average measurement.

Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces preliminary holes at assembly to 15/64" size.

* DRILL METHOD CODING: S-2 = Spacematic - Hand-held reaming.

Spacematic, airpowered drill and accessory tooling.

3. Hand-held, air powered drill driving a piloted reamer prepares all holes for the cold working and on a follow-up operation produces the final hole size per Engineering.

4. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 928 data entries were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.248657" as evidenced per the Executive Summary by Data Lot. Some holes are nearly perfect and hereinafter are discussed along with the holes bearing characteristics detracting from otherwise very good holes.

1. Three (3) holes are nearly perfect specimens. Computer Individual Printout discloses the total range of thirty-two (32) measurements per hole as follows:

Hole #	Range
1	0.000181"
3	0.000579"
28	0.000172"

The above holes are excellent and outstanding considering the hand reaming operation performed to achieve their final size.

2. Several holes within this set exhibit a few dimensions out of the thirty-two (32) per hole that exceed the 0.2500" established per Engineering. They will be discussed first for their cause and affect on hole geometry and finally for their affect on hole quality.

Hole Individual Computer Profiles disclose side loading as the single characteristic geometrically inherent in this set for all holes except those related in item III.A.1 above. Side load forces may be traced along the principal axes (0° - 45° - 90° - 135°) of the holes via the Computer Printout Tapes. They disclose that the axes exhibiting the greatest affect of side load forces are also:

a. The same axes disclosing the oversize dimensions.
b. Feature significantly in the information of the hole exit area bellmouth/or taper.
c. Are constituent axes in the calculation of the largest ovality measurements. The plane level of the ovality measurement is common to the oversize plane level.
d. Axes featuring the greatest side load affect are always adjacent to each other.

The following table is derived from individual holes exhibiting the oversize dimensions and illustrate items "a" and "d" above.
For relationship to Bellmouth and ovality, items "b" and "c", refer to the Individual Computer Printout,

Hole #	Side Loaded Axes	Plane Levels Disclosing Oversize Dimensions and Affected Axis
4	90° - 135°	7, 8, @ 90°; 8 @ 135°
6	0° - 135°	7, 8 @ 0°; 7, 8 @ 135°
8	0° - 135°	7, 8 @ 0°; 7, 8 @ 135°
10	0° - 135°	8 @ 135°
11	0° - 45°	7, 8 @ 0°; 7, 8 @ 45°
13	90° - 135°	8 @ 90°
15	45° - 90°	8 @ 45°
19	0° - 45°	7, 8 @ 0°
20	0° - 135°	4 thru 8 @ 0°; 5 thru 8 @ 135°; 6, 7, 8 @ 45°
21	0° - 45°	8 @ 0°; 8 @ 45°
23	0° - 45°	7, 8 @ 0°; 7 @ 45°
25	0° - 135°	7, 8 @ 0°
27	0° - 135°	7, 8 @ 0°; 7 @ 45°

Generally, the side load condition exists as a bulge in the hole along the affected axes and is smoothly tapered as it approaches the exit plane of the hole. The specific oversize "spikes" recorded on the Computer Printout as "Highest Reading" for the holes presented in the preceding table are as follows:

Hole #	Highest Readings	Axis and Plane Level
4	0.250957"	135° @ 8
6	0.250517"	135° @ 8
8	0.250155"	135° @ 8
10	0.250069"	135° @ 8
11	0.250698"	0° @ 8
13	0.250379"	90° @ 8
15	0.250328"	45° @ 8
19	0.251043"	0° @ 7
20	0.251164"	0° @ 8
21	0.250267"	45° @ 8
23	0.250129"	45° @ 8
25	0.250172"	0° @ 8
27	0.250233"	45° @ 7

The readings above are significant in pointing out the fact that 77% of the oversize conditions exist at plane #8 (the exit of the hole in the material stack) and the remainder are approximately 1/8" prior to exiting the hole. The oversize values are only a minute amount over the Engineering high tolerance and have no degrading affect on the quality of the hole except in the case of Hole #20.

Hole #20 exhibits slightly oversize conditions along its 0° - 45° and 135° axes. The hand reaming operation is considered the cause and side load affect is apparent along the noted axes over one half the length of this hole.
The purpose of delineating all of the statistics on the aforenoted holes is to apprise the host facility of the quality and success of its <u>spacematic drilling</u> which will become apparent as the remainder of this audit is reviewed. A process change from hand reaming to spacematic drilling on these holes may be worth a second look. Spacematic drilling with your present existing tooling, we strongly feel would produce a hole of superior quality; be more consistent on size than hand-reaming and eliminate the side load affect.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #4 and discloses a value of 0.002207" at plane level #8 on the 45° - 135° axes. Hole #4 Individual Profile discloses a relatively straight taper enlargement from plane #4 through to break-out at plane #8. This condition is suggestive of operator instability during the hand reaming operation resulting in a side load enlargement of the hole.

Ovality on this set is greater than all other hole series at this facility. The cause has been stated as side load due to hand reaming.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azmuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident throughout this set in varying amounts as indicated per item III.A.2. The holes of this group exhibit the bellmouth/taper condition at their exit plane of drilling and reaming. Cause has been related to side loading resulting from hand reaming instability.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and spar, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-1

RANKING NUMBER 56

HOLE SIZE 0.185"/0.188"

I. <u>OVERVIEW:</u>

A. This set of production holes features double margin piloted tip drilling of the Aft Bulk Cargo Door. The structure is an all aluminum stack of three (3) laminates of structure incorporating a gray colored "rubbery" textured sealant material between faying surfaces at all layup interfaces. The hole is sized by Engineering at 0.185"/0.188" for HiLok Fastener installations.

Hole survey measurements were obtained using a Diatest Split-Ball Gage that incorporates an Alina linear displacement measurement transducer and is coupled to an Automated Computer System for data storage and recovery.

II. <u>SUMMARY:</u>

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated pre-drilled fuselage skins for basic hole locations. A standard designed hand-held drill block was used as the "steering guide" for drilling of holes to final size requirement. A hand-held, air powered, drill motor driving a double-margin piloted tip drill was employed to obtain a "one-shot" final sized fastener hole. A piloted tip countersink (standard tooling DJ-570), with micro-stop control was used for fastener countersink angle and depth control. Reaming was not required, nor planned, in order to achieve final hole size integrity and finish texture.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.185680", an excellent feature since the low and high limit criterion is 0.185"/0.188" respectively as established per Engineering. Hole #3 reveals an out of tolerance measurement at 0.188603". Thie hole along with other specific characteristics relating to these holes are discussed in detail at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed major fixturing ensures structure alignment and positioning reliability.

2. Hand-held, air powered drill method and accessories are adequate to the production of good quality holes. Reaming not a requirement.

* DRILL METHOD CODING: H-1 - Hand-held drill, No reaming
Gen. Dynamics std. hand-held drill block, steering guide. No reaming.

3. Hand-held drill block incorporating drill guide bushings is adequate to ensure hole alignment. A double margin piloted tip drill was used for "one-shot" drilling operation to hole final sizing.

4. Planning is adequate to direct manufacturing and inspection operational requirements. Close tolerance holes are inspected by sampling per planning direction.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced. This series of holes were outstandingly good for a hand drilling technique.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary by Data Lot." 348 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.185680" which is excellent especially considering the drilling mode to be a hand operation.

b. Hole #3: Reference Individual Hole Profile Printout. This hole exhibits an oversize condition (0.188603") at the entrance plane of the drill to hole which disappears entirely as depth in the hole is acquired and rigidity is achieved. The phenomenon is suggestive of drill "lead-in grab" since it occurred at the start plane of the hole and is evident at only one location (0^{o} axis at level #1) and vanishes thereafter. The condition does not repeat as depth in hole is acquired and is therefore considered extremely insignificant to hole quality.

c. Hole #5 discloses one (1) undersize dimension, 0.184914", at the entrance plane of the hole and its 0^{o} orientation axis. This dimension was <u>discounted via analysis</u> and physical <u>on site visual inspection at 10X magnification</u>. The undersize reading was a result of the split-ball probe riding onto the sealant material that had seeped out of the faying surfaces and onto the hole sidewall. Visual inspection confirmed the smeared sealant inside of the hole. Ordinary swabbing would not remove the substance. Fastener installation sheared off the substance with no hole degradation.

d. Holes #5, 10 and #13 are examples offering evidence of drill "lead-in" and/or "breakout-load" affect enlarging the vicinity of the entrance and/or exit planes of several holes. The "bellmouth" or "taper" is extremely subtle

since its overall dimensions are well within the tolerance bounds established by Engineering.

e. The "Executive Summary Histogram" for this set discloses a dimensional population crowding the extreme low limit of the tolerance which is excellent. The slope tendency in the vicinity of the 0.186000" zone is brought about as a result of the "bellmouth" or "taper" exhibited by the examples described in item "d" above, while the low limit (0.185000") is representative of the basic drilled hole for this set.

B. Ovality: a. Ovality throughout this set of holes was affected most by the "lead-in" and "breakout loads" enlarging either the entrance or exit planes of the holes and creating the "bellmouth" and/or "taper" which in turn reflects on ovality. The condition is insignificant since the entire set of holes meet the Engineering tolerance.

C. Perpendicularity: The holes of this set were by design too small to accept the Angle/Azimuth Gaging Device plug to determine perpendicularity via this means. Hi-Lok fasteners were installed in several holes and head gap was inspected for perpendicularity of the hole. In addition, the concentricity of the countersink to the hole shank was visually checked at 3X magnification. The holes were perpendicular to the skin contour.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Generally evident as indicated by profile analyses. This characteristic was precipitated as a result of hand tooling and operator instability. Reference Item III.A. for details.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through a stacked arrangement of hardware was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except in the areas where the gray sealant impinged onto the hole sidewalls.

DRILL METHOD H-2

RANKING NUMBER 57 *

HOLE SIZE: 0.250"/0.254"

I. OVERVIEW:

A. This set of production holes features freehand drilling and reaming of holes in the Fuel Tank, Aft Fuselage.

The structure is all aluminum lay-up of skin and fitting whose approximate thickness is 0.25" in the area being surveyed. The subject hole is sized by Engineering at 0.250"/0.254" for installation of ANX8 (NAS 1448) Steel High Shear Rivets.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production was freehand drilling and reaming. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.253013" for the set of twenty-nine (29) holes. This value is exceptionally high since it resides at the extreme high vicinity of the Engineering tolerance range. Most of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Freehand air powered drilling is employed to produce preliminary holes.

3. Freehand reaming using a piloted reamer and handheld guide bushing produces the final sized holes.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

* DRILL METHOD CODING: H-2 - Hand-held Drill and Ream.
Freehand air powered drill & freehand reaming using a piloted reamer & handheld guide bushing.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. CHARACTERISTICS:

A. Hole Size: 348 data entries were accrued for the series of holes. The arithmetical average for the set is 0.253013", very close to the 0.254" high limit per established Engineering Criterion. The affect of instability on vertical freehand operations is apparent on the size and shape features of the holes in this set. The most predominant geometric feature traceable to the method of production is taper and/or bellmouth at either the entrance and/or exit vicinities of the holes attributable to operator instability and center-seeking on the reaming. The feature exists but is within the tolerance per Engineering Criterion.

1. Basic hole size is generally within tolerance limits as evidenced by the individual measurements of the holes. Range is the predominant factor in determining hole shape for this set. A series of measurements taken at twelve (12) locations within each hole were as follows:

Hole #	Range	Hole #	Range
1	0.001302"	16	0.001086"
2	0.000603"	17	0.000907"
3	0.000338"	18	0.001267"
4	0.001900"	19	0.000595"
5	0.001017"	20	0.000457"
6	0.000569"	21	0.000564"
7	0.001802"	22	0.000414"
8	0.000750"	23	0.000836"
9	0.000629"	24	0.000798"
10	0.000776"	25	0.000809"
11	0.000509"	26	0.000853"
12	0.000825"	27	0.000415"
13	0.000647"	28	0.001034"
14	0.000758"	29	0.001534"
15	0.000983"		

2. Reference Individual Hole Computer Printouts. The relative thinness of the structure favors operator instability and subsequent hole enlargement on start of drilling and upon final breakout. Most of the holes in this set crowd the high limit of the tolerance. The high readings are primarily due to bellmouth and/or taper conditions inherent in the structure per the above.

3. Reference Individual Hole Histograms generally disclose a distribution populated closely together but at the upper limit of the tolerance. The bellmouth and/or taper is accountable for the data distribution. The Executive Summary Histogram for this set exhibits a spread covering a 0.002000" between 0.252" and 0.254" into the oversize range for the same reason. This magnitude is not uncommon in freehand operations such as in this set.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #7 and recorded at 0.001302" at Level #3 on the 0°-90° axes. This value is negligible and does not cause quality degradation of the hole. Ovality was a function of center-seeking in reaming brought about via subtle operator instability.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be acceptable on ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90°) to the longitudinal axis of the holes.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile Analyses.

F. Bellmouthing: This characteristic has been addressed per narrative at item III.A. and III.A.2. The feature is slight and does not violate the tolerance criterion established per Engineering.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 58 *

HOLE SIZE: 0.376"/0.378"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of the Aft Fuselage. The structure is aluminum approximately .660" thick at two (2) 206-031-329 fittings and .470" at two (2) 206-031-327 fittings that were drilled and reamed along with the closure bulkhead. The subject hole is sized by Engineering at 0.376"/0.378".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized a major custom built assembly fixture to assure hole location. Holes were drilled by Buckeye air powered hand-held drill and fixture lock-on guide bushing. Reaming was accomplished in like fashion with the Buckeye Hand-held drill motor and a modified tip 0.3760" reamer. Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose Arithmetical Average is 0.376348" for the set of twenty nine (29) holes. The holes of this series were of excellent quality. First glance at the Computer Data Printout reveals both oversize and undersize conditions are evident in several holes. Data analysis and on-site observations documented the causes for both anomalies which are discussed in detail at paragraph III.A. All holes of this set were well within the Engineering established tolerance criterion.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of excellent holes:

* DRILL METHOD CODING: H-2 = Hand-held drill and ream.

Buckeye hand-held, air driven motor w/Buckeye, hand-held drill for reaming.

II. C. (Continued)

1. Major custom fixturing ensures interchangeability and location reliability.

2. The Executive Summary Histogram reveals the data distribution characteristics of a Normal Gausian Distribution indicating that tooling, processes and personnel in harmonious control.

3. The "Executive Summary by Data Lot" reveals the average of all measurements to be 0.376348", centered about lowest point of the tolerance spread, an ideal characteristic for hole size.

4. Detail planning is adequate for the definition of the operational steps required to product the part and hole inspection requirements.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary" for this set. 811 measurements were recorded for this series of twenty-nine (29) holes. The average reading 0.376348" is excellent since it crowds the low range of the Engineering tolerance.

b. Holes #1, #2, #6, #10, #14 and #22 exhibiting oversize conditions were discounted by analysis and onsite observation as non-existant. The oversize for all holes occurred at the entrance plane of the air-probe and the oversize readout resulted from the deburring chamfer being slightly large and consequently the air-probe sensed the condition as oversize. Hole #22 oversize readout was the result of a slight shallow angle scratch at the entrance plane of the hole.

c. It was documented prior to performing air-probe measurements that several holes yield spots of zinc chromate primer and/or slight primer over-spray

III. A. c. (Continued)

on their sidewalls. The holes are correct, and the Computer Printout reflects the result of the primer film on the sidewall. Reference Holes #1, #3, #4, etc., for typical examples of primer impingement.

d. Reference to the Individual Profile Analyses disclose the hole to be slightly "tapered" or "bellmouthed" up to a magnitude approaching 0.001" in some cases. The condition begins at the <u>entrance plane of the reamer</u> and gradually enlarges with depth toward the <u>exit plane</u> of the hole. This condition results from <u>subtle side loads</u> induced by operator during reaming. Drill weight moment arm and operator influence percipitates the characteristic "taper", "oval" or "bellmouth".

B. Ovality: The greatest ovality occurred at one of the oversize holes; namely, Hole #22, and was the result of the scratch influence at 0.002000" at the 0^{o}-90^{o} axes planes. Ovality generally is good with the distribution ranging below 0.0005". Item III.A.d. above describes the influence of the operator on ovality.

All other holes met the Engineering tolerance criterion by exhibiting measurements of 0.001" or less.

C. Perpendicularity: Perpendicularity is assured via custom fixturing and axis of the vertical drill press.

D. Straightness: Straightness is within Engineering tolerance by fact of acceptance of the "thru-hole" air probe and plug gages to full length of the holes.

III. (Continued)

E.	Barrelling:	This feature is the predominant characteristic exhibited by this set of holes as previously related. Reference to Individual Hole Profiles of the Computer Printout bear witness to the geometry. Refer to profile printout of Holes #9, #15, #19, etc., for verification.
F.	Bellmouthing:	Evident on occasion as indicated by the profile analyses buy overwhelmed by the "barrelling" feature.
G.	Hole Texture:	Rifling, Scratches, Chatter marks. This set of holes exhibited a satin finish interior wall texture. There was occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. The "barrelling" effect within the holes was detectable only by air probe profile computer printout. There were no chatter marks nor vertical scoring in these holes.
H.	Burrs:	This set of holes was drilled and reamed through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.
I.	Surface Finish:	All holes of this set exhibited a surface finish of "100 AA". Optical surface comparator was used in this inspection. Surface was smooth and of satin texture in the aluminum section of the holes. The steel elements of the structure were bright and shiny and surface finish considerable better than "100 AA".

.DRILL METHOD H-3

RANKING NUMBER 59 *

HOLE SIZE: 0.249"/0.253"

I. OVERVIEW:

A. An automated measuring system utilizing a thru-hole air probe coupled to a Hewlett Packard 9815A Programmable Calculator was used to accumulate, store and produce a Computer Statistical Printout of each hole of this set. The Computer Statistical Printouts of individual holes provide composite clues leading to disclosure of the geometric features of the holes related to their measurement profiles.

II. SUMMARY:

A. Siz (6) holes were available in the noted aircraft for survey inspection on a non-interference basis.

B. Tolerance criterion of 0.249000"/0.253000" was arbitrarily established as measurement limits for these holes for purposes of collecting computer data via thru-hole air probe. The structure at approximately 0.40" thick permitted an acquisition of sixteen (16) data points for each hole to establish profile characteristics of the specimens and reveal their geometric features.

III. CHARACTERISTICS:

A. Hole Size: 96 data measurements were accrued for the series of six (6) holes. Reference, Executive Summary by Data Lot discloses an arithmetical average of 0.253828" for this set. This average supports a supposition that the manufacturers design criterion was 0.2500"/0.2540" and the fasteners were 1/4" Flush Head Jo-Bolts.

* DRILL METHOD CODING: H-3 = Hand Held Drilling; Cold Worked Hand Held Reaming

III. A. (Continued)

1. Reference Individual Hole Computer Printouts. All of the holes of this set are bellmouthed at either the top or bottom measurement planes and their measurement range from highest reading to lowest within each hole is exhibited via the following chart:

Hole #	High	Low	Range
1	0.254862"	0.252190"	0.002672"
2	0.255043"	0.252966"	0.002077"
3	0.254207"	0.253009"	0.001198"
4	0.255940"	0.253121"	0.002819"
5	0.254216"	0.252638"	0.001578"
6	0.255431"	0.253259"	0.002172"

The general bellmouth and/or taper at the top or bottom of these holes most probably results from "center-seeking" of the drill at its start plane and chip build up where the slight oversize exhibits itself at the break-out plane of the hole.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #2 and discloses a value of 0.002069" on the 0^{o}-90^{o} axes at plane level 1. Ovality is the product of the bellmouth feature in this hole.

Ovality in the series generally ranges between 0.001"/0.002" and is a function of the bellmouth features of the holes.

C. Perpendicularity: Inspection was performed via 10X magnification. The holes were normal to their longitudinal axis and acceptable to established Engineering criterion.

III. (Continued)

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in subtle amounts as indicated by holes referenced in III.A. and III.A.1 narrative.

G. Hole Texture: Inspection omitted by oversight on this set of holes.

H. Burrs: There was no evidence of burrs in the assembly.

I. Surface Finish: Omitted by error on this set of holes.

DRILL METHOD S-1

RANKING NUMBER 60 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling of the Skin to Frame, Center Flap Assembly. The structure is an all aluminum stack whose thickness in the area to be surveyed is approximately 0.50". The subject hole is sized by Engineering at 0.2460"/0.2500" for installation of Flush Hi-Lok bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. All holes are in complete compliance with all Engineering criterion. Measurement data was accumulated at twenty (20) locations within each hole via "thru-hole" air probe. Quality of the holes will be discussed in detail at paragraph III, along with other geometric features of these holes.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.248175" for the set of twenty-nine (29) holes. This value is a very good feature since it resides at the mid-point of the Engineering tolerance range.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces good holes at assembly without follow-on reaming.

* DRILL METHOD CODING: S-1 = Spacematic, One-shot, No reaming.

Spacematic, airpowered drill & accessory tooling.

II. C. (Continued)

3. Reaming was not a requirement in the production of these holes.

4. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The dividend of this concept is good production holes at this facility.

5. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 580 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.248175", is an ideal characteristic in regard to the Engineering criterion of 0.2460"/0.2500". This is a very good series of holes on size. Reference to Computer Individual Hole Printout discloses the following:

1. Four (4) holes are nearly perfect with their total spread of twanty (20) measurements per hole having recorded the following range:

Hole #	Range	Comment
7	0.000492"	See Note*
14	0.000362"	
15	0.000431"	
20	0.000405"	

Note* Generally a very subtle ovality at the start plane of drilling or at the exit plane is the feature accounting for otherwise perfectly drilled holes.

III. A. (Continued)

2. The remainder of the holes comprising the series comply with all Engineering tolerance criterion on size and shape.

3. Reference Individual Hole Computer Printout. Two (2) characteristics detract from otherwise excellent holes and are identified as follows:

   a. Bellmouth and/or taper at the entrance vicinity of the holes. Holes #11, #17, #19 and #27 are representative examples.

   b. Bellmouth and/or taper at the exit vicinity of the holes. Holes #4, #5 and #18 are representative examples.

   The cause for the taper featured at the start plane of the holes is suggestive of minor drill "seeking" of the tip on drill entry since the oval feature is <u>rather uniform</u> at all axes of measurement.

   The cause for the taper and/or bellmouth at the exit vicinity of the holes is suspected as drill heat generated by the absence of coolant. The exit areas also are uniform on axis distribution of the taper feature suggesting chip load build-up prior to breakout.

4. Several holes, namely Hole #2, #8, #12 and #24 disclose an enlargement (not in excess of the Engineering tolerance) at the <u>start plane</u> of drilling. This feature is <u>discounted</u> as cause for concern. The feature, extremely uniform in magnitude, is an impingement of the countersink

III. A. 4. (Continued)

along the vertical wall of the hole "picked up" by the air-probe. The feature has been disallowed as cause for concern in analysis of the holes.

5. Reference Executive Summary by Data Lot. The range of measurements for this set is 0.003595" as an aggregate series and all measurements are within the tolerance allowables of 0.2460"/0.2500". Individual Hole Computer Printout discloses the range of measurements to be very good. Ten (10) holes, slightly exceeded 0.001" total ranges, are displayed as follows in increasing order of magnitude:

Hole #	Range
29	0.001021"
8	0.001026"
17	0.001028"
10	0.001052"
6	0.001071"
27	0.001121"
16	0.001156"
4	0.001172"
18	0.001690"
23	0.001255"

All other holes of the set were less than 0.001" in total range of measurements.

The reader is reminded of the fact that the Profile Displays on the Computer Printout when exhibited by the figure "0", is representative of 0.0001" per "0"; thus, it follows, we are dealing in very minute deviations in this series of holes.

III. (Coninued)

B. Ovality: Maximum recorded ovality within the set occurred at Hole #23 and discloses a value of 0.000960" at plane level #1 on the $45^{o}-135^{o}$ axes. Enlargement at the entrance plane of measurements was due to a spike in the countersink impinging onto the hole sidewall. The magnitude is well within the Engineering tolerance criterion and is not a detracting feature for hole quality.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in minute and subtle amounts as indicated by holes identified per item III.A.3.a. and III.A.3.b. Various other holes of this set exhibit the same condition at their

III. F. (Continued)

entrance and exit planes; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel and frame was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-2

RANKING NUMBER 61 *

HOLE SIZE: 0.3090"/0.3110"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Aircraft Wing Splice Installation. The structure is the right hand wing bottom panel. The area for hole survey is the right hand wing bottom panel. The area for hole survey is the inboard and outboard rows of 5/16" fasteners identified WZ 10 (HL19PB; HiLok Flush Bolts), located 0.68" and 1.86" inboard from the toe of the main splice forging at WS 110.00. The assembly is approximately 0.70" thick in the area being surveyed and the subject holes are sized per planning at 0.3090"/0.3110".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey. The method of production featured preliminary Spacematic drilling of the structure followed by hand reaming of the holes to achieve final Engineering size. Measurement data was accumulated at thirty-two (32) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.310429" for the set of twenty-nine (29) holes. Normally the aforenoted average would be considered an acceptable feature since it resides within the parameter of the high limit of the Engineering tolerance range; however, there is an adverse inherent "bellmouth" characteristic throughout this series of holes.

Owing to the bellmouth feature, 59% of the holes of this set exceed the 0.3110" high limit, at the reamer entry vicinity of the holes.

Specific discussion on the geometric characteristics of the holes, including the condition above, are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes.

* DRILL METHOD CODING: S-2 = Spacematic, Hand-held reaming.

Spacematic, air driven power unit w/hand-held air powered drill driving piloted reamer.

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Spacematic, air driven power unit produces preliminary holes prior to hand reaming to their final Engineering size.

3. Reaming is accomplished via hand-held air powered drill motor driving a piloted reamer to acquire final hole size at 0.3090"/0.3110".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 927 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.310429", is deceptive in the face of an inherent bellmouth feature exiting on the holes.

1. Reference Individual Hole Computer Printouts.
The bellmouth feature exists at the entrance plane of the holes which is the outer surface of the wing in regard to the direction of drilling and proceeds at a diminishing taper rate until depth in the hole forces alignment and a consistent diameter hole is achieved. Generally, this condition is not acquired until the operator is 30% or more through the assembly stack.

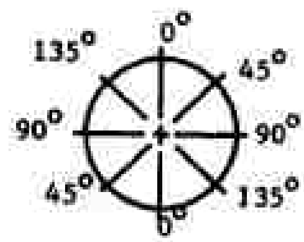
   The bellmouth and/or taper condition is the most predominant detrimental geometric feature to overall hole quality on this series of holes.

2. Reference Individual Hole Computer Printouts for Holes #1 through #11, #13,#14,#18,#19,#20,#21 and #28.
The above noted eighteen (18) holes are oversized in a bellmouth mode on all axes of measurement and diminish at a relatively consistent rate as depth in the hole is achieved.
The condition is suggestive of chatter (center-seeking) of the reamer pilot since all axes are equally affected on magnitude. Operator instability on tool handling (drill motor) during its duty cycle in reaming also has an influence on the final profile configuration of the holes.
Reference note #1 on page 4.

3. Reference Individual Hole Computer Printouts for Holes #12,#15,#16,#17,#22 through #27 and #29. These holes exhibit the affect of operator side loading during the hand reaming operation. Operator instability on hand operations is distinguished by hole enlargement along the axis/or adjacent axes where the load was applied as illustrated by the Computer Profile Data:

Hole #	Axis Axes Affected
12	0^{o}-135^{o}
15	0^{o}-45^{o}
16	90^{o}-135^{o}
17	0^{o}-135^{o}
22	45^{o}-90^{o}
23	0^{o}-45^{o}
24	45^{o}-90^{o}
25	0^{o}
26	90^{o}-135^{o}
27	90^{o}-135^{o}
29	0^{o}-45^{o}

Note: On axis oriented measurements the 0^{0} and 135^{o} are adjacent.



4. Reference Executive Summary Histogram. The data profile for this set populates the entire tolerance/oversize zones and feastures various spikes. The data is indicative of the hole variations experienced via the bellmouth feature discussed in the aforementioned text. Additionally, there is an inherent instability associated with hand-held drill/reaming operations when assist tooling is not employed to help control vertical alignment and eliminate side load influence.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #17 and discloses a value of 0.001879" at plane level #1 on the 45^{o}-135^{o} axes. Enlargement ovality at this plane of measurements results from side loads induced via operator instability during reaming resulting in enlargement along the 135^{o} axis. The affect of operator side loading has been discussed in the narrative per item III.A.3.

Ovality is affected by the taper and operator side load on these holes and its magnitude a function of the oversize conditions.

C. Perpendicularity: Absence of an appropriate plug to accommodate this hole size would not permit inspection via the Azimuth Angle Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The longitudinal axes of the holes are normal (90°) to the skin outer surface and acceptable to established Engineering criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident throughout this set in varying amounts as indicated per item III.A.1. through item III.A.3. The holes of this group exhibit the bellmouth/taper condition at their entrance plane of drilling and reaming. Cause has been related to "center-seeking" resulting from hand reaming instability and operator instability during the reaming cycle.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There was only very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel, shim and splice forging, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 62 *

HOLE SIZE: 0.250"/0.254"

I. OVERVIEW:

A. This set of production holes features "one-shot" drilling and counter-sinking of the Wing Upper Surface.

The structure is an assembly of aluminum skin and stringers whose thickness is approximately 0.31" in the areas being surveyed. The subject hole is sized by Engineering at 0.250"/0.254" for installation of NAS1580A, Flush Head High Shear Bolts located at the second and third stringers forward of the rear spar.

II. SUMMARY:

A. Twenty-nine (29) holes were surveyed from one (1) available assembly on the factory line. The method of production utilized the Spacematic air driven power head for drilling and counter-sinking. Spray-mist coolant integrally coupled to the powerhead provided adequate cooling during the duty cycle of the drill, and drill stalls were not noted during the processing of this series of holes. Measurement data on the holes was accomplished via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.251310" for the set of twenty-nine (29) holes. This value is an excellent feature since it resides at the low vicinity of the Engineering tolerance range. All of the holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling producing satisfactory "one-shot" full sized holes at assembly.

3. Reaming was not a requirement for the holes at this work Station.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

* DRILL METHOD CODING: H-1 = Hand-held drill, no reaming.

General Dynamics std. hand-held drill block, steering guide. No reaming.

III. CHARACTERISTICS:

A. Hole Size: 348 data entries were accrued for the series of holes. The arithmetical average for the set is 0.251310", well below the 0.254" high limit per established Engineering Criterion. This is a very good series of holes on size but are characteristically tapered and/or bellmouthed. The most predominant geometric feature traceable to the method of production is slight taper and/or bellmouth at the exit plane vicinities of the majority of the holes, attributable to drill chip build-up. The feature exists but is well within the tolerance per Engineering Criterion.

1. Range measurement values are the predominant factor in determining hole shape for this set. A series of measurements taken at twelve (12) locations within each hole were as follows:

Hole #	Range	Hole #	Range
1	0.000586"	16	0.000610"
2	0.001991"	17	0.001017"
3	0.001767"	18	0.000207"
4	0.002013"	19	0.002095"
5	0.001966"	20	0.000517"
6	0.000569"	21	0.000257"
7	0.001897"	22	0.000983"
8	0.001176"	23	0.001057"
9	0.001209"	24	0.000569"
10	0.001210"	25	0.000819"
11	0.000695"	26	0.000269"
12	0.000422"	27	0.000345"
13	0.000754"	28	0.001000"
14	0.001248"	29	0.000647"
15	0.001003"		

2. Reference item III.A.1. and Individual Hole Computer Printouts.
Five (5) holes, identified Hole #12,#18,#21,#26 and #27 are nearly perfect specimens. There are no flaw features evident in the computer data nor apparent in the physical holes via 3X magnification by Sight Pipe inspection.

3. Reference Individual Hole Computer Printouts.
All other holes of this set (item III.A.2 excepted), exhibit the taper and/or bellmouth characteristic. All of the specimens are well within the tolerance criterion established per Engineering and the feature at worst case is only 0.002" in magnitude at Holes #2, #4 and #19.

4. The Histograms, both Summary by Lot and Individual, reflect a utilization of nearly all of the tolerance band owing to the taper built into the hole by chip loading. The start of drilling yields the smallest diametrical records and increase as depth and chip load increase.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #8 and recorded at 0.000750" at Level #5 on the 45^{o}-135^{o} axes. Ovality in this hole results from slight "center-seeking" of the drill at the start of its duty cycle.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Holes for this set were checked by gaging with 10X Azimuth/Angle Gaging Device and verified to be normal (90^{o}) to the longitudinal axis of the holes.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile Analyses.

F. Bellmouthing: This characteristic has been addressed per narrative at item III.A, and III.A.3. The feature is extremely slight and does not violate the tolerance criterion established per Engineering.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited very good interior sidewall texture. There was occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 63 *

HOLE SIZE 0.4991"/0.5006"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Rear Spar Outboard Fitting. The fitting is aluminum 7075 forging, approximately 0.281" machined thickness at the tongue to be measured for hole quality. The subject hole is sized at 0.4991"/0.5006" per Engineering.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The tongue of the forging to be drilled and reamed was located via custom fixturing and drill plate integral to the fixture. Hole measurements for this set were obtained by "thru-hole" air probe and were recorded for subsequent computer printout.

The method for production of the subject holes was custom fixturing employing a "flip-up" drill location plate and incorporating adapters for Quackenbush air-powered drill. Reaming was accomplished by hand-held air powered drill motor and a piloted reamer for final reaming to size.

B. These holes disclose a measurement distribution whose arithmetical average is 0.500894" for the set of twenty-nine (29) holes. This average exceeds the high limit of the Engineering tolerance spread of 0.4991"/ 0.5006". Three holes, identified Hole #5, #13, #27 are within the Engineering tolerance and are discussed in detail at paragraph III.A. along with the oversize condition of these holes.

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand held air powere reamer

Quackenbush air power drill w/hand-held air feed drill for reaming.

II. (Continued)

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush air powered drill used for drilling with accessory drill plate integral to the fixture.

3. Hand-held air powered drill motor, piloted reamer and slip fit reamer guide bushing for final reamer sizing of the finished holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary" for this set. 348 measurements were accrued for this series of holes. The Arithmetical Average for the set is 0.500894" with related cause defined in the following text.

b. Two (2) holes, identified Hole #5 and #13, were within the Engineering criterion 0.4991"/0.5006". Hole #27 exhibited only one spur recorded as 0.500603", located at its 90° axis of measurement and at the entrance to the hole. This spur, caused by slight chip load variation is very insignificant and Hole #27 was considered acceptable.

c. Hole #26, the largest of the series ranged from 0.501026" to 0.505871". Reference to the Statistical Printout discloses a constant tapering condition from the outer surface of the spar (0.501026"), to the far side plane of the fitting tang (0.505871").

III. A. (Continued)

d. Hole #24, the second largest of the series, ranged from 0.502181"/0.503672". Reference to the Statistical Printout discloses virtually a straight oversize condition between 0.502"/0.503".

e. The remainder of the holes disclose an oversize condition ranging from 0.0001" to 0.0004" in excess of the Engineering high limit (0.5006").

NOTE: Refer to the "Executive Summary Histogram" and the Individual Hole Histograms. All records, including the acceptable holes are consistently crowding the high limit of the tolerance and beyond. Areas suspect for cause of the oversize are:

1. "Rattle space" between the reamer and reamer guide bushing sidewalls caused by a worn guide bushing.

2. "Rattle space" between the reamer and reamer guide bushing and the reamer "seeking" the bushing sidewall owing to subtle movement of the powerhead by the operator during hand reaming.

B. Ovality: The greatest ovality naturally occurred at one of the oversize holes; namely, Hole #24. Ovality generally is good with the distribution less than 0.0005". Hole #23 discloses least ovality as 0.000043" and 0.000034".

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined face (interface surface). Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

III. (Continued)

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through a clevis arrangement of flanges, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "63AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 64 *

HOLE SIZE: 0.2460"/0.2500"

I. OVERVIEW:

A. This set of production holes features drilling of the Center Wing Rear Spar, Left and Right Hand Sides. The structure is an all aluminum stack-up of web and rear spar cap whose approximate thickness is 0.56" in the area subject to survey inspection. The subject hole is sized by Engineering at 0.2460"/0.2500" for HiLok Bolt installation.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production featured Spacematic, single step ("one-shot" drilling), utiilizing a double margin drill and freon coolant. Reaming was not planned nor employed. Measurement data was accumulated at twenty-eight (28) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.248714" for the set of twenty-nine (29) holes. All of the holes except one (1) meet the criterion established by Engineering. Specific discussion concerning the geometric characteristics of the holes are discussed at paragraph III along with Hole #6, the only hole exhibiting an oversize condition.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces final sized holes at assembly on a "one-shot" operation. Operator handling of the drill during its duty cycle is apparent in the completed holes.

3. A Tool Set-Up Station is maintained in the vicinity of the work area. Spacematic drills are set up and adjusted by a tooling specialist who performs a sample run to ensure proper operation and adjustment on tooling. The divident of this concept is good production holes at this facility.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

* DRILL METHOD CODING: S-1 = Spacematic, One-shot, No reaming.

Spacematic, air power drill & accessory tooling.

III. CHARACTERISTICS:

A. Hole Size: 812 data measurements were accrued for the series of holes. The arithmetical average for the set 0.248714", is a very good feature with regard to the mid-point range of the Engineering criterion at 0.248000". Only one (1) hole, identified Hole #6, exhibits a bellmouth condition at its entrance vicinity of the drill which is oversize to the tolerance.

Reference to Computer Individual Hole Printout discloses the following:

1. Hole #6 exhibits a smoothly tapering slightly oversize bellmouth condition to a depth of 0.15" into the hole. The maximum oversize is 0.000483" at the entrance to the hole. It achieves an acceptable tolerance at Plane level #3 and remains within tolerance thereafter.

   Operating handling of the drill drive unit during its duty cycle is suggested as cause for the bellmouthing characteristic and resultant oversize condition. Several other holes, namely Hole #9, #12, #14, #18, #22, #23, #24 and #25 disclose a similar bellmouth feature but remained within the allowable tolerance spread permitted by Engineering criterion. Additional holes also reflect operator side-load influence on the drill during its duty cycle but to a lesser degree.

2. Reference to Individual Computer Printout discloses a rather respectable overall measurement range from the highest to lowest reading within the twenty-eight (28) measurements per hole. The range of measurements are as follows:

Hole #	Range	Hole #	Range
1	0.001293"	16	0.001665"
2	0.001407"	17	0.000651"
3	0.001448"	18	0.001381"
4	0.001435"	19	0.001897"
5	0.001284"	20	0.002879"
6	0.002397"	21	0.001457"
7	0.002043"	22	0.002043"
8	0.000825"	23	0.001905"
9	0.002095"	24	0.001819"
10	0.002129"	25	0.001364"
11	0.000616"	26	0.001828"
12	0.001534"	27	0.001914"
13	0.001233"	28	0.002233"
14	0.001509"	29	0.001910"
15	0.001224"		

Focus onto the above measurement ranges was for the purpose of drawing attention to the fact that this series of holes would have been better had it not been for the operator induced bellmouth and side-load characteristics.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #28 and recorded at 0.001095" at Level #3 on the 0^o - 90^o axes. The ovality feature of Hole #28 is directly related to side loaded condition enlaraging its axes measurements.

Ovality is not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be acceptable on the ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Hole size tolerance criterion would not permit inspection via the Angle/Azmuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in varying magnitude as indicated by Holes referenced at Item III.A.1. Various other holes in this set exhibit the same condition at their entrance plane of drilling but to a much smaller value.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited acceptable interior wall texture. There was evidence of rifling at a shallow angle of approximately 20^o. Inspection was performed by Sight Pipes at 3X magnification. There were not vertical scoring marks inside the holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: Generally, the holes of this set exhibited a surface finish of "125 AA". Optical surface comparator was used in this inspection. Surfaces were occasionally marred by "galling" due most probably to drill heat up owing to lack of coolant.

DRILL METHOD H-1

RANKING NUMBER 65 *

HOLE SIZE 0.185"/0.188"

I. OVERVIEW:

A. This set of production holes features double margin piloted tip drilling of the Skin to Header Tees. The structure is an all aluminum stack of three (3) laminates of structure incorporating a gray colored "rubbery" textured sealant material between faying surfaces at all layup interfaces. The subject hole is sized by Engineering at 0.185"/0.188" for Hi-Lok Fastener installations.

Hole survey measurements were obtained using a Diatest Split-Ball Gage that incorporates an Alina linear displacement measurement transducer and is coupled to an Automated Computer System for data storage and recovery.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated pre-drilled fuselage skins for basic hole locations. A hand-held drill block was used as the "steering guide" for drilling of holes to final size requirement. A hand-held, air powered, drill motor driving a double-margin piloted tip drill was employed to obtain a "one-shot" final sized fastener hole. A piloted tip countersink (standard tooling DJ570), with micro-stop control was used for fastener countersink angle and depth control. Reaming was not required, nor planned, in order to achieve final hole size integrity and finish texture.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.186008", a desirable feature since the low and high limit criterion is 0.185"/0.188" respectively as established per Engineering. Hole #12 reveals an out of tolerance measurement

* DRILL METHOD CODING: H-1 = Hand-held Drill, No reaming.

Hand-held, air powered drill & accessories. No reaming.

II. B. (Continued)

at 0.188388". This hole along with other specific characteristics relating to these holes are discussed in detail at paragraph III.

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom designed major fixturing ensures structure alignment and positioning reliability.

2. Hand-held, air powered drill method and accessories are adequate to the production of good quality holes. Reaming not a requirement.

3. Hand-held drill block incorporating drill guide bushings is adequate to ensure hole alignment. A double margin piloted tip drill was used for "one-shot" drilling operation to hole final sizing.

4. Planning is adequate to direct manufacturing and inspection operational requirements. Close tolerance holes are inspected by sampling per planning direction.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary by Data Lot". 464 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.186008".

b. Hole #12: Reference Individual Hole Profile Printout. This hole exhibits an oversize condition at the entrance plane of the drill to hole which disappears entirely as depth in the hole is acquired and rigidity is achieved. The phenomenon is suggestive of operator instability since

c. Hole #19: This hole discloses one oversize spur deep in the hole at its 135^{o} axis on level 3. The dimension, 0.188345" is 0.000345" oversize, and is the result of negligible "chip scarring". It is extremely shallow in depth, less than one (1) ninety degree (90^{o}) quadrant in length and is of very shallow angle with regard to the vertical centerline of the hole. One additional measurement, 0.188060", which occurs at the entrance plane of the hole, was alos eliminated via analysis as negligible affect on the degradation of hole quality.

d. Holes #15, 21, 25, 26 and #29 all disclose one (1) or several dimensions within their series to be undersize. All of these dimensions were <u>discounted via analyses</u> and physical <u>on site visual inspection at 10X magnification</u>. The undersize readins were the result of the split-ball probe riding onto the sealant material that had seeped out of the faying surfaces and onto the hole sidewalls. Visual inspection confirmed the smeared sealant inside of the holes. Ordinary swabbing would not remove the substance. Fastener installation sheared off the substance with no hole degradation.

e. Holes #3, 9 and #11 offer evidence of operator side-load affect enlarging the vicinity of the exit plane of several holes as defined in item "b" above. The all dimensions are within the tolerance bounds established by Engineering.

f. The "Executive Summary Histogram" for these holes disclose full utilization of the entire tolerance spread. The out of tolerance conditions are explained in items b, c, and d above. The tendency toward the high limit of the tolerance is brought about by the "bellmouth" or "taper" exhibited by the examples descirbed in items b and e above while the low limit band of the tolerance is representative of the basic hole.

B. Ovality:

a. The greatest ovality of the set occurred at Hole #15, level #3 and was recorded at 0.003707". This hole is <u>disqualified</u> since the cause of the ovality is sealant impingement onto the hole sidewall. The 0.181888" dimension at the 0^{o} axis resulted in the extreme ovality disclosure; likewise, the 0.182681" dimension at the 45^{o} axis precipitates the 0.002888" figure reported on the Individual Hole Printout for ovality at the 45^{o}-135^{o} axes.

Discounting the affect of the sealant, the ovality values for Hole #15 are 0.000628" at level #1 on the 0^{o}-90^{o} axes and 0.000482" at level #1 on the 45^{o}-135^{o} axes.

b. Ovality throughout this set of holes was affected by the side loads induced by the drill operator. The condition is insignificant since the entire set of holes meet the Engineering tolerance and range generally less than 0.0006". Several holes lay in the vicinity of 0.001" on ovality which is well within the Engineering tolerance allowable.

C. Perpendicularity: The holes of this set were by design too small to accept the Angle/Azimuth Gaging Device plug to determine perpendicularity via this means. Hi-Lok fasteners were installed in several holes and head gap was inspected for perpendicularity of the hole. In addition, the concentricity of the countersink to the hole shank was visually checked at 3X magnification. The holes were perpendicular to the skin contour.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Generally evident as indicated by profile analyses. This characteristic was precipitated as a result of hand tooling and operator instability. Reference Item III. A. for details.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through a stacked arrangement of skin and "Tee" headers was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "63 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except in the areas where the gray sealant impinged onto the hole sidewalls.

DRILL METHOD Q1

RANKING NUMBER 66 *

HOLE SIZE 0.249"/0.254"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Forward Spar. The structure is an aluminum forging whose thickness is 0.625" in the vicinity of drilling/reaming and the subject hole is sized by Engineering at 0.249"/0.254".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production employed custom fixturing to assure hole location. Holes were drilling by Quackenbush airpowered drill with automatic feed but non-automatic retract. Drilling was followed by hand-held air feed drill motor powering a piloted reamer to obtain final hole sizing. Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose arithmetical average is 0.252733" for the set of twenty-nine (29) holes. This average tends toward the high limit of the Engineering tolerance spread of 0.249"/0.254". Four holes, identified Hole #4, #9, #17 and #22 exceeded the Engineering tolerance and are discussed in detail at paragraph III.A.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush drill method and accessories producing good holes.

* DRILL METHOD CODING: S-1 = Spacematic, One shot, no reaming. Spacematic drilling. No reaming.

3. Hand held air powered drill motor utilizing a piloted reamer and parts restrained by the assembly fixture produces acceptable final sizing of the hole.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. CHARACTERISTICS:

A. Hole Size: All holes except Holes #4, #9, #17 and #22 were within the allowable Engineering criterion of 0.249"/0.254". Holes individually were good on size with the average of all 928 recordings being 0.252733."

Refer to the "Executive Summary Printout." The Histogram reveals a Flat, Wide Gausian Distribution fairly evenly displayed on peaks. Areas suspect for cause of the wide distribution are:

1. "Rattle space" between the reamer and reamer guide bushing sidewalls caused by a worn guide bushing.

2. "Rattle space" between the reamer and reamer guide bushing caused by a reamer sized toward the mid range of the tolerance and "seeking" the bushing sidewall owing to subtle movement of the powerhead by the operator during hand reaming.

3. Uneven chip load during the hand reaming operation caused by slight wobble of the powerhead.

NOTE: Condition #2 above appears the most logical cause for this set of holes disclosing a trend toward the high limit of the tolerance:

A. The holes are predominantly sized between the 0.252"/0.253" range.
B. The ovality of the holes is consistently in the range of "Tenths of Thousandths" indicating control of "whip" and little operator side loads.
C. The out of tolerance holes #4, #17 and #22 disclose a characteristic indicating <u>side loads</u> caused the problem, i.e., #4 side loads predominantly at 0^{o} to 45^{o} axes; #17 at the 90^{o} axis, and #24 at the 135^{o} axis.
Hole #9 evidences the greatest side loads at the 0^{o}-45^{o} axes but additional wavering causing continuation of oversizing to the remaining 90^{o} and 135^{o} axes.

B. Ovality: The greatest ovality naturally occurred at one of the oversize holes; namely, Hole #4. Ovality generally is good with the distribution less than 0.001". Hole #20 discloses least ovality as 0.000397" and 0.000483" at levels 8 and 2 respectively. The spurs in the profile for Hole #20 are indicative of irregular chip load during drilling/reaming.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined face (interface surface). Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 67 *

HOLE SIZE 0.185"/0.188"

I. OVERVIEW:

A. This set of production holes features air powered Spacematic drilling of the Skin to Intercostal Side Pa[illegible]. The structure is an all aluminum stack of three (3) laminates of structure approximately .300" thick. The subject hole is sized by Engineering at 0.185"/0.188" for Hi-Lok Fastener installations.

Hole survey measurements were obtained using a Diatest Split-Ball Gage that incorporates an Alina linear displacement measurement transducer and is coupled to an Automated Computer System for data storage and recovery.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated Spacematic drilling for the basic hole locations. Reaming was not required, nor planned, in order to achieve final hole size integrity and finish texture.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.186467", a desirable feature since the low and high limit criterion is 0.185"/0.188" respectively as established per Engineering. One (1) hole identified Hole #6 reveals out of tolerance measurements. This hole along with other specific characteristics relating to these holes are discussed in detail at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of good holes:

1. Custom designed major fixturing ensures structure alignment and positioning reliability.

2. Spacematic, air powered drill method and accessories are adequate to the production of good quality holes. Reaming not a requirement.

3. Planning is adequate to direct manufacturing and inspection operational requirements.

4. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

* DRILL METHOD CODING: S-1 = Spacematic, One shot, no reaming. Spacematic drilling. No reaming.

III. CHARACTERISTICS:

A. Hole Size:

a. Reference "Executive Summary by Data Lot". 232 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.186467" and hole finish at "100 AA" is excellent.

b. Hole #6 exhibited two (2) spikes of oversize measurements at 0.188931" and 0.188914" respectively on its 0^{o} and 45^{o} measurement axes. Chip loading (clogging) is suggested as cause for the oversize results of drilling. The oversize, limited to the vicinity of the exit plane of the hole, no doubt is a result of drilling completion and breakout occurring shortly beyond the second plane of measurements.

c. Fourteen (14) holes, identified #4, #6, #7, #8, #12, #16, #17, #18, #19, #21, #23, #24, #26 and #27 disclose a trend whereupon the exit plane of measurements exceed the start plane of measurements. Chip loading as stated in "b" above is suggested as cause for this enlargement condition in the holes. Relative thinness of the cross-sectional thickness of the material stack-up precluded hole size growth to the point of exceeding the Engineering tolerance criterion. All holes of this set remained within tolerance zone.

d. The "Executive Summary Histogram" for this set discloses full utilization of the entire tolerance spread. The out of tolerance conditions explained in item "b" and the tendency toward the high limit of the tolerance per item "c" are contributing conditions driving the Histogram over its full value spread. A second look at the drilling technique is suggestive by the trend data.

B. Ovality:

a. Hole #6 yields the greatest ovality of this set at 0.002621" for its 0^{o} - 90^{o} axes and at Level #2. The cause for the 0.002621" readout is obvious resulting from the out of tolerance condition of the hole. The remainder of the holes offered no cause for concern. All holes remained within the confines of Engineering tolerance limits.

C. Perpendicularity: The holes of this set were by design too small to accept the Angle/Azimuth Gaging Device plug to determine perpendicularity via this means. Fasteners were installed in several holes and head gap was inspected for perpendicularity of the hole. In addition, the

concentricity of the countersink to the hole shank was visually checked at 3X magnification. The holes were perpendicular to the skin contour.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Generally evident as indicated by profile analyses. This characteristic was precipitated as a result of chip loading as drilling approached the exit plane. Reference Item III.A. for details.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through a stacked arrangement skin, doubler and intercostal member was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA". Optical Surface Comparator was used in this inspection. Surface was smooth and shiny except in the areas where the gray sealant impinged onto the hole sidewalls.

DRILL METHOD Q-2

RANKING NUMBER 68*

HOLE SIZE 0.5000"/0.5030"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Rudder Attach Fitting. The structure is titanium. The flange to be drilled and reamed are tapered by design with regard to the holes. Heavy fixturing provides interchangeability on alignment and drill/reaming angle. Hole longitudinal axis is perpendicular to the aircraft vertical centerline. The flanges vary from approximately 0.375" to 0.500" thick at the locations for the holes.

The hole being inspected is sized at 0.5000"/0.5030" by Engineering.

II. SUMMARY:

A. Twenty-nine (29) holes were inspected in this set. Although this structure was titanium, it was available on the production line on a non-interference basis; therefore, inspection was performed by "thru-hole air probe" to broaden our base of knowledge on production drilling/reaming.

The computer data Statistical Printout for this series of holes provides a dimensional and statistical composite traceable to the following for the production of good holes:

1. Good fixture design for interface control/interchangeability reliability and Quackenbush drill adaptation.

*DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical
Rockwell air drive motor for drilling & Quackenbush air drive for reaming.

2. Rockwell air drive motor for drilling and Quackenbush air drive motor for reaming and accessories producing good holes.

3. Planning is excellent for inspection traceability on holes. Also, planning specifies "certified mechanic required for the drilling and reaming of these holes".

4. "Drill Kit & Pre-Set Orders (DKPO) identified in the planning provides the technician performing the drill/reaming task with a freshly inspected, cleaned, controlled set of new or refurbished tools (drill motor, drills reamers, bushings, etc.) to accomplish a specific task on a one time use only basis.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

B. A unique situation existed on this set of holes as follows:

1. The material was a heavy titanium fitting of multiple vertical tangs.

2. The operation was line drilling and reaming through these multiple tangs.

3. The face of the tang on the outboard sides (entry face for the drill and reamer) was canted with regard to the drill/reamer longitudinal axis.

4. Holes were line drilled with a Rockwell air feed drill, plug gaged for size, then line reamed with a Quackenbush air feed motor to final size.

III. CHARACTERISTICS:

A. Hole Size: Eight (8) holes of this set of twenty-nine (29) slightly exceeded the Engineering tolerance of 0.5000"/0.5030". The conditions existing on the oversize holes were as follows:

Hole #4: Generally this hole ranged from 0.0003" to 0.0004" oversize in diameter. The roundness of the hole was good and no other flaws were detectable.

Holes #10, #11, #12, #17 and #19 were all only 0.0001" over the Engineering criterion of 0.5030". The cause of the slight oversize condition is suspected to be chip load and taper (per design) in the fitting flange. The oversize condition shows up in the center of the flange thickness and at the exit side of the drill/ream operation on the flange.

NOTE: At hole #17 one dimension at the entry side of the flange read 0.499017". This dimension is in error caused by particle blockage of the air probe used by the Survey Team. Discounting this measurement the Range of measurements for Hole #17 is 0.000422" in lieu of <u>0.004086"</u>.

Hole #24 shows an oversize condition recorded as 0.503190"/0.503543". The oversize is at the last plane of four measurements and the exit side of the drill/reamer onto a tapered surface. Breakout loads probably are the cause of this slight anomaly.

Hole #28 exhibits a similar condition except that the oversize exists at the entry side of the fitting flange with regard to drill/reamer. Since only one measurement (0.503483") out of twelve

exhibits the 0.0004" OS, it is suggested to be a start "grab" into the tapered flange face.

B. Ovality: Discounting Hole #17 on ovality owing to the measurement error stated in (III.A), Hole #24 exhibits the greatest ovality as 0.003310" at the 0^{o} - 90^{o} axes at Level #3. All holes were acceptable on ovality measurements.

The cause of ovality in this set of holes generally is attributable to engagement or breakout of the drill/reamer on a tapered face and some chip load where it occurs in the center of the flange thickness.

C. Perpendicularity: Hardware design presents canted outer faces not normal to the drill/reamer longitudinal axis. The holes by design and fixture control are normal (90^{o}) to the Vertical Axis of the aircraft. Perpendicularity is guaranteed by tooling, line reaming and next assembly interface pin-up.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of parts exhibited a very good interior texture. There were slight brinnell indications on one fitting caused by sling pins used to hoist the assembly for movement. The affected holes were not oversized to the Engineering tolerance. There were no chatter

marks nor vertical scoring in this set of holes.

H. Burrs: This set of holes were line drilled and reamed through the fitting flanges. Deburring was satisfactorily accomplished in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately "63AA". Optical Surface Compator and Sight Pipes were used in this inspection. Surface was smooth and shiny except for the brinnelling ("100 AA") as noted in III.G.

DRILL METHOD H-2

RANKING NUMBER 69 *

HOLE SIZE 0.250"/0.253"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Drag Angle for the Vertical Stabilizer. The structure is aluminum skin (0.180" thick) and a titanium drag angle (0.200" thick). The hole being inspected is sized at 0.250"/0.253" by Engineering.

II. SUMMARY:

A. Owing to limited accessibility, this set of holes were measured from inside the tail structure, starting at the skin inside moldline and proceeding outboard through the titanium drag angle which nests onto the skin outside moldline. "Thru-hole" air probe measurements therefore were taken opposite to the direction of drilling and reaming of the holes. The hole measurements and profile readouts on the computer tape printout are as follows:

1. The first plane of measurements/profile is equivalent to the drill/reamer exit plane in the aluminum skin.

2. The last plane of measurements/profile is the start point and/or entrance of the drill/reamer into the titanium drag angle.

B. Three (3) holes of this set exceed the Engineering tolerance limits of 0.250"/0.253". These holes, numbered #4, #12 and #20 are discussed in detail at paragraph III.A.

C. The computer data Statistical Printout for this series of holes provides a composite traceable to the following for the production of good holes:

1. Custom fixturing was not required to locate the holes.

2. Hand held drill/reaming method and accessories were adequate to produce a good set of holes.

3. Planning is excellent for inspection traceability on holes.

4. Good tooling on a planned periodic refurbish program, coupled with the mandatory requirement for technician to draw new and/or currently refurbished/reinspected drills and reamers from production tool cribs for use on the job is evident in product quality.

* DRILL METHOD CODING: H-2 = Hand-held Drill and Ream. Hand-held drill/reaming and accessories.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. CHARACTERISTICS:

A. Hole Size: All holes except Hole #4, #12 and #20, were within the allowable Engineering criterion of 0.250"/0.253". Holes are individually excellent on size. Measurements taken at 12 to 16 locations within each hole yield an average value of 0.251195."

Hole #4 and #12 exhibit an oversize condition at the exit plane of the aluminum skin and at the entrance plane of the titanium drag angle. Breakthrough wobble coupled with manually held guide tooling is the most logical cause for this phenomenom. Drill cutting action is the greatest at the extremes when considering the center portion of the total thickness as the pivot point.

Hole #4 recorded 0.254052"/0.253716" at Level #1 and 0.253362"/0.253129" at Level #4.

Hole #12 recorded 0.255241"/0.254802" at Level #1 and 0.256897"/0.256741" at Level #4.

Hole #20 discloses only one (1) diametrical measurement out of tolerance (0.254112"). This phenomenon is most probably chip load at the breakout point causing the one spur reading. This hole is not significant enough to be considered an out of tolerance hole.

The trend in measurements is indicative of tooling producing ideal holes since the yield of all measurements provides an average size of 0.251195", tending toward the midpoint of the tolerance spread.

B. Ovality: Maximum recorded ovality within the set was 0.003310" at Hole #20. Individual holes within this set (12 to 16 measurements per hole) ranged to as low as 0.000043" at Hole #24.

The cause for the slight ovality within this set of holes is considered the result of instability on the hand held bushing guide for reaming. Ovality is predominately at the start (entrance) to the hole at the titanium drag angle and is very slight. Ref. Computer Printout, the last measurement plane in the data printout is the titanium drag angle (drill start plane).

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Very slight as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed by hand method and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "63 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 70*

HOLE SIZE 0.500"/0.505"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Engine Air Duct Assembly.

The hardware varies from approximately 0.50" to 0.75" thick in the area of the holes and the subject holes are sized by Engineering at 0.500"/0.505" for installation of MS21297-08 High Shear Steel Bolts.

B. The structure being surveyed is a series of heavy machined aluminum bulkhead fittings located at various fuselage stations and butt lines. Hardware from three (3) Duct Assemblies were used to accrue sufficient holes for the survey set.

II. SUMMARY:

A. Nineteen (19) holes were available in this structure for survey inspection. The method of production utilized heavy drill plates, located and clamped to the affected fittings to facilitate locking on the Quackenbush air driven power head. The parts were drilled with the fuel shelf faying surface of the hardware nested to the drill plate. Tapered shims integral to the drill plate compensate for the fuel shelf angle and ensure that the drilling/reaming axes are normal (90^{o}) to the nut and head surfaces of the final assembled structure. The drill bit is coolant fed via two (2) shank ports integral to the drill bit and supplies pressure fed coolant at the chisel tip land. Quackenbush bench drilling followed by reaming was accomplished outside of the major final assembly fixture on Holes #1 through #11. Holes #12 through #19 were drilled and reamed via Quackenbush method with the hardware positioned in the assembly fixture and

*DRILL METHOD CODING: Q-2 = Quackenbush, Air power reamer, mechanical.

Quackenbush, air powered drill and accessory tooling.

at a different assembly area. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.501699" for the set of nineteen (19) holes. This value is a very good feature since it resides at the lower-mid vicinity of the Engineering tolerance range. All of the holes of this set except Hole #9 and Hole #11 meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces good preliminary holes at assembly.

3. Quackenbush, air powered drill, deriving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go/No-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 716 data entries were accrued for the series of nineteen (19) holes. The arithmetical average for the set is 0.501699", well below the 0.505" high limit per established Engineering

Criterion. This is a very good series of holes on size and shape features considering the fact that bench drilling/reaming were employed to achieve final hole size and several set-ups were performed at various fuselage station bulkheads. The most predominant geometric feature apparent via data analysis for this set is slight taper and/or bellmouth in the holes. The feature exists but is well within the tolerance per Engineering Criterion.

1. Basic hole size was extremely consistent as evidenced by the range measurements of the set. Range also is the predominant factor in determining hole shape for this set. A series of measurements taken at thirty-two (32), forty-four (44), or fifty-two (52) locations within each hole, dependant upon the thickness of the hardware, were as follows:

Hole #	Range	Hole#	Range
1	0.000741"	11	0.004086"
2	0.001207"	12	0.001095"
3	0.000698"	13	0.000466"
4	0.001233"	14	0.001241"
5	0,000543"	15	0.000793"
6	0.000388"	16	0.000690"
7	0.000276"	17	0.000629"
8	0.000569"	18	0.000664"
9	0.004284"	19	0.000647"
10	0.000768"		

2. Reference I.B.; Holes #1-#4 and Computer Printouts. All four (4) holes exhibit a straight tapering/bellmouth feature. Chip load build-up is suggested as cause owing to the progressive, evenly distributed build-up and its affect on all four (4) axes.

3. Reference I.B.; Holes #5-8 and Computer Printouts. The series of holes at this location are very good specimens. Holes #6 and #7 are nearly perfoect having only 0.000388" and 0.000276" range respectively in their entire series of thirty-two (32) measurements per hole.

Holes #5 and #8 exhibit an extremely slight side load enlargement along their 90°-135° axes. The condition is so subtle that weight moment on the drill power unit from a slightly loose cam lock-up of the unit resulted in side load ovality. (Note: Gravity line was along the 90° axis of the holes during the measurement process). Refer to item III.A.1 above for the range measurements on these holes.

4. Reference I.B.; Holes #9-#11 and Computer Printouts. Hole #9 exhibits a bellmouth condition at its entrance plane. The feature exceed the Engineering high limit (0.505"), exhibiting a maximum value of 0.506198" at level #1. "Center-seeking" at the start of reaming is suspect for cause since all axes are affected and relatively the same order of magnitude. The flaw area is very shallow to a depth of 5/32" into the hole in structure that is approximately 0.75" thick. Hole #10 is a very good hole exhibiting only 0.000768" variation in fifty-two (52) measurements in a 0180" thick part.
Hole #11 discloses a chip gouge at plane level #2 and a maximum recorded value of 0.506190" at its 90° axis. The scar is negligible, occurring at plane level #2 then disappearing completely at plane level #3. After healing from the flaw at level #2, this hole is exceptionally good on size and shape by varying only 0.000500" maximum over the remaining 11/16" of hole depth.

5. Reference I.B.; Holes #12-#19 and Computer Printout. Holes #12 through #15 are very similar. All are well within the tolerance allowable per Engineering. All exhibit hole enlargement to a very slight degree from chip load as depth into the hole acquired. Chip load is suggested for cause since all axes are affected and the growth is progressive and regular. Holes #16 through #19 exhibit very subtle side load enlargement along their 90° and 135° axes. Cause for growth along the 90° and 135° axes is suggestive of the weight moment on the drill. Refer to narrative at III.A.3., Holes #5 and #8.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #1 and recorded at 0.000474" at Level #1 on the 45° - 135° axes. This value is negligible and does not cause quality degradation of the hole.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. Holes were checked by gaging with 10X magnification Azimuth/Angle Gaging Device and disclosed at 1° closed angle owing to the fuel shelf interface from which the measurement was taken. This angle is correct for the interface. Upon assembly of upper and lower halves of the bulkhead (fuel shelf sandwiched between the fittings), the final longitudinal axis of the hole with regard to the nut and head of the bolt is normal (90°) and no gaps are evident. Refer to paragraph II.A for tooling compensation description.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidence by profile analyses.

F. Bellmouthing: This characteristic is the most predominant geometric feature of the set. Bellmouthing and/or taper has been defined on affected holes in the narrative per III.A.2. through III.A.5.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of parts exhibited a very good interior hole sidewall texture. There were occasional shallow angle rifling

perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q1

RANKING NUMBER 71*

HOLE SIZE 0.375"/0.379"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of a Fuselage Rear Spar Assembly. Cross-sectionally the structure is approximately 2.00" thick. After looking forward the stack consists of a rear spar fitting (Find #25), cap (Find #2), doubler (Find #7), web (Find #38), cap (Find #2) and fitting (Find #25).

The lower section of the spar is of similar nomenclature except that the find numbers are 26, 39, 7, 38, 3 and 26. The holes subject for survey are sized by Engineering at 0.375"/0.379".

II. SUMMARY:

A. Twenty-nine (29) holes were available to provide the required sample size for the survey.

The method of production employed custom fixturing to assure hole location. Holes were drilled by Quackenbush air powered drill with automatic feed. Reaming was accomplished in the fixture by hand-held air feed drill motor powering a piloted reamer to obtain final hole sizing. Inspection measurements were obtained by "thru-hole" air probe.

B. All of the holes for this set are well within the tolerance spread established by Engineering and average overall at the mid-point range of the tolerance. Reference to the "Executive Summary by Data Lot" reveals the average hole size to be 0.376691", a desirable feature since the low to high limit criterion is 0.375000"/0.379000" respectively. The specific characteristics for these holes are discussed in detail at paragraph III. along with Hole #9, which exhibited one (1) oversize measurement at 0.379379".

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand-held Air Power Reamer Quackenbush, air powered drill w/auto. feed. Reaming w/hand-held air feed drill.

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush drill method and accessories producing good holes.

3. Hand held air powered drill motor utilizing a piloted reamer produces good final sizing of this set of holes; however, an additional <u>hand reaming</u> operation performed by the operator has an effect on slightly degrading the <u>roundness</u> integrity of some holes. Paragraph III.A. elaborates on details.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS:</u>

A. Hole Size: a. Some of the holes of this set exhibit a "saw-tooth" effect owing to the hand reaming operation performed by the technician to recover hole alignment on the stack-up which was lost as a result of riveting along the upper and lower caps. Subtle shift in the lamination of parts presented installation of normal 3/8" bolts. Additional hand reaming was necessary to facilitate installation of the required assembly hardware. This phenomenon will be discussed at Ovality, item B. of this paragraph.

1. Three holes of this set, namely Hole #9, #16 and #27 disclosed <u>one dimension each</u> out of tolerance:

#9: 0.379397" at 90° alignment, Level #3.
#16: 0.379034" at 0° alignment, Level #6.
#27: 0.379078" at 0° alignment, Level #3.

The above oversize dimensions are too insignificant to discredit the quality of the hole size. Cause of the oversize spur is chip scarring since it occurs only once in each hole; it is at one axis point within the plane dimensions of each hole; it is exceedingly shallow and in each case it disappears at the next plane level of measurements.

2. Reference "Executive Summary Histogram by Data Lot." The measurement distribution utilizes the entire tolerance range owing to the second reaming operation which is evident in measurement population. The initial hole is distributed about 0.375000" and 0.376000". The second reaming operation relates to the 0.377000" to 0.379000" distribution.

B. Ovality:

a. The "saw-tooth" effect, a produce of rereaming of the holes after riveting to regain hole alignment results in hole ovality. A second ovality effect results from operator instability on hand reaming outside of the drill fixture and using the physical assembly hardware as the reamer guide. In this case ovality and taper are induced into the hole until sufficient reamer depth is obtained to provide vertical/perpendicular stability.

NOTE: There is a material interface plane at Level #10.

b. Holes #1, #3, #7 and #26 are examples of ovality induced by reaming to obtain realignment to accept the 3/8" bolt on assembly. Note the oversize "spike" that occurs at plane #10. This area is the deburring chamfer existing on the outer fitting and on the spar cap chord. These "spikes" are discounted for concern during the hole analysis process.

c. Holes #2, #5, #6, #8, #22 and #27 are examples of ovality and taper induced primarily by operator instability. Note also the stagger point at plane #10.

d. Ovality overall within these holes all fell within the tolerance criterion 0.375000"/0.379000" established per Engineering. Individual Hole Profile Computer Printout offer the disclosure of individual hole profiles.

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the centerline of fuselage station 69.203 and spar fitting machined faces (interface surface). Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses and general characteristics. Taper and ovality are the predominate features of this series of holes.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 72 *

HOLE SIZE: 0.375"/0.380"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Engine Air Duct Assembly.

The hardware averages approximately 0.37" thick in the area of the holes and the subject holes are sized by Engineering at 0.375"/0.380" for installation of MS21297-06 High Shear Steel Bolts.

B. The structure being surveyed is a series of heavy machined aluminum bulkhead fittings located at various fuselage stations and butt lines. Hardware from two (2) Duct Assemblies were used to accrue sufficient holes for the survey.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production utilized heavy drill plates, located and clamped to the affected fittings to facilitate locking on the Quackenbush air driven power head. The parts were drilled with the fuel shelf faying surface of the hardware nested to the drill plate. Tapered shims integral to the drill plate compensate for the fuel shelf angle and ensure that the drilling/reaming axes are normal (90^{o}) to the nut and head surfaces of the final assembled structure. The drill bit is coolant fed via two (2) shank ports integral to the drill bit and supplies pressure fed coolant at the chisel tip land. Quackenbush bench drilling followed by reaming was accomplished outside of the major final assembly fixture. Inspection measurements were obtained via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.376210" for the set of twenty-nine (29) holes. This value is an ideal feature

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical.

Quackenbush, air powered drill & accessory tooling.

since it resides at the low-point vicinity of the Engineering tolerance range. <u>All</u> of the holes of this set meet the criterion established by Engineering. There are two (2) minor features of <u>taper</u> and/or <u>bellmouth</u> apparent in the Individual Hole Computer Printout Data for these holes. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces good preliminary holes at assembly.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go/No-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 472 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.376210", well below the 0.280" high limit per established Engineering Criterion. This is an excellent series of holes on size and shape features considering the fact that bench drilling/reaming were employed to achieve final hole size and several set-ups were performed at various fuselage station bulkheads.

1. Basic hole size was extremely consistent as evidenced by the range measurements of the set. Range also is the predominant factor in determining hole shape for this set. The range of measurements taken at sixteen (16) locations within each hole are as follows:

Hole #	Range	Hole #	Range
1	0.000198"	16	0.000517"
2	0.000440"	17	0.001380"
3	0.000560"	18	0.000310"
4	0.000345"	19	0.001077"
5	0.000560"	20	0.000175"
6	0.000353"	21	0.000440"
7	0.000397"	22	0.000764"
8	0.000345"	23	0.001121"

(cont'd next page)

9	0.000259"	24	0.002578"
10	0.000110"	25	0.000241"
11	0.002259"	26	0.000552"
12	0.000293"	27	0.000224"
13	0.000216"	28	0.000362"
14	0.000250"	29	0.000819"
15	0.000595"		

2. Reference I.B.; Holes #1-#4 and Computer Printouts. Hole #3 discloses an ovality condition at plane level #1. The feature is the result of "center-seeking" of the reamer at the start of its engagement into the hole. The flaw is extremely slight and disappears at the next plane of measurements inside the hole. The remaining holes, identified Hole #1, #2 and #4 are nearly perfect specimens.

3. Reference I.B.; Holes #5-8 and Computer Printouts. Hole #5 reveals a tapered enlargement of the hole along its 90° and 135° xes. The condtion is suggestive of side loading on the drill power head induced by operator handling during its duty cycle; thus, only two (2) adjacent axes of the hole were affected by subtle enlargement. Holes #6,#7 and #8 reveal a very slight taper at their entrance planes and is characteristically heaviest at the 45° axes. Lead-in side loading is suggested as cause for the taper along with reamer pilot misalignment on concentricity with the preliminary hole.

4. Reference I.B.; Holes #9-#12 and Computer Printouts. Hole #11 reveals a bellmouth condition at its entrance plane. The feature is well within the Engineering high limit (0.380"), exhibiting a maximum value of 0.377974" at level #1. "Center seeking" at the start of reaming is suspect for cause since all axes are affected and at relatively the same order of magnitude. Holes #9,#10 and #12 are nearly perfect specimens per Computer Profile Printout.

5. Reference I.B.; Holes #13-#16 and Computer Printout. Holes #15 and #16 exhibit a taper and/or bellmouth at the vicinity of their drill/reaming exit planes. Chip build-up loads are responsible for the hole enlargement. The build-up is progressive and regularly distributed among all four (4) measurement axes. Holes #12 and #13 are virtually perfect specimens per Computer Profile Printout.

6. Reference I.B.; Holes #17-#20 and Computer Printout. Holes #19 exhibits a taper/bellmouth at its exit plane vicinity. Chip build-up during drilling which failed to clean up during reaming is suspect for cause owing to the "spiked" plane level #4 in this hole. Reaming could not cause the abrupt "spike" condition. Hole #17 exhibits a slight lead-in "grab" resulting in an ovality spur at level #1 and a spike at its exit plane similar to Hole #19. Cause for the exit plane feature is identical to Hole #19. The lead-in

grab most probably results from reamer pilot misalignment to the preliminary hole.
Holes #18 and #20 are nearly perfect specimens per Computer Profile Printout.

7. Reference I.B.; Holes #21-#22 and Computer Printout. Hole #21 is nearly a perfect hole, marred only by a slight chip-scar at level #2. The scar is extremely slight and disappears at the next plane depth within the hole.
   Hole #22 is very similar to Hole #11 (item #4 above) and exhibits an entry taper/bellmouth condition. "Center-seeking" at the start of reaming is suspect for cause since all axes are affected and at the same order or magnitude.

8. Reference I.B.; Holes #23-29 and Computer Printout. Hole #23 reveals chip-scarring at plane level #3 on all four axes; then, migrating down to plane level #4 at its 0° and 45° axes. Drill chip-load gouging that failed to clean up in reaming is suggested as cause owing to the shape and spike magnitude within the hole.
   Hole #24 discloses a similar condition as exists in hole #23. Cause is also identical to hole #23.
   Holes #25 and #27 are flawless.
   Holes #26 and #28 are very similar and exhibit side load influence at two (2) adjacent axes. The condition diminishes as depth in hole is acquired. Hole #26 is affected along its 0° and 45° axes. Operator induced sideloading is suggested as cause in both holes, resulting from drill handling during its duty cycle.
   Hole #29 exhibits a straight tapering bellmouth feature. Chip load build-up and release is suggested as cause owing to the progressive, evenly distributed build-up, all axes affected and suddenly released, signifying break-off and clearing.

9. Reference to Individual Hole Historams reveals a Normal Gausian Distribution and data populated about the 0.376000" vicinity. This distribution offers evidence supporting a conclusion of process, tools and personnel operating in harmony.
   Reference to the Executive Summary Histogram for this set disclose sporadic departures away from the 0.376000" site. Holes #11,#17,#19,#22,#23,#24 and #29 are the <u>contributors</u> responsible for break-in cluster continuity. The aforenoted holes exhibit a range spread out of the ordinary for these holes. Reference III.A.1 and Individual Computer Printout Data.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #24 and recorded at 0.002552" on the 45°-135° axes. Ovality resulted from the lead-in side load along its 45° axis. The value does not exceed the tolerance

criterion permitted per Engineering.
Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on their ovality measurements. None of the holes of this set exceeded the Engineering Criterion.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. Holes were checked by gaging with 10X magnification Azimuth/Angle Gaging device and disclosed a 1° closed angle owing to the fuel shelf interface from which the measurement was taken. This angle is correct for the interface. Upon assembly of upper and lower halves of the bulkhead (fuel shelf sandwiched between the fittings), the final longitudinal axis of the hole with regard to the nut and head of the bolt is normal (90°) and no gaps are evident. Refer to paragraph II.A. for tooling compensation description.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: This feature has been defined on affected holes of this set in the narrative per III.A.3. through III.A.7.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of parts exhibited a very good interior hole sidewall texture. There were occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-2

RANKING NUMBER 73*

HOLE SIZE: 0.4375"/0.4425"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Engine Air Duct Assembly.

The hardware varies from approximately 0.50" to 0.80" thick in the area of the holes and the subject holes are sized by Engineering at 0.4375"/0.4425" for installation of MS21297-07 High Shear Steel Bolts.

B. The structure being surveyed is a series of heavy machined aluminum bulkhead fittings located at various fuselage stations and butt lines. Hardware from two (2) Duct Assemblies were used to accrue sufficient holes for the survey.

II. SUMMARY:

A. Twenty (20) holes were available in this structure for survey inspection. The method of production utilized heavy drill plates, located and clamped to the affected fittings to facilitate locking on the Quackenbush air driven power head. The parts were drilled with the fuel shelf faying surface of the hardware nested to the drill plate. Tapered shims integral to the drill plate compensate for the fuel shelf angle and ensure that the drilling/reaming axes are normal (90°) to the nut and head surfaces of the final assembled structure. The drill but is coolant fed via two (2) shank ports integral to the drill bit and supplies pressure fed coolant at the chisel tip land. Quackenbush bench drilling followed by reaming was accomplished outside of the major final assembly fixture. Inspection measurements were obtained via "thru-hole" air probe.

*DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical.

Quackenbush, air powered drill and accessory tooling.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.439125" for the set of twenty (20) holes. This value is a very good feature since it resides at the lower-mid vicinity of the Engineering tolerance range. All of the holes of this set except Holes #15 through Hole #17 meet the criterion established by Engineering. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of very good holes.

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Quackenbush, air powered drill and accessory tooling produces good preliminary holes at assembly.

3. Quackenbush, air powered drill, driving a piloted reamer achieves final hole size per Engineering.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go/"no-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 688 data entries were accrued for the series of twenty (20) holes. The arthmetical average for the set is 0.439125", well below the 0.4425" high limit per established Engineering Criterion. This is a very good series of holes on size and shape features considering the fact that bench drilling/reaming were employed to achieve final hole size and several set-ups were performed at various fuselage

station bulkheads.

An apparent disclosure per data analysis for this set is slight barrelling on Holes #2, #11, and #19. The feature exists but is well within the tolerance per Engineering Criterion. In addition, Holes #15, #16, and #17 are slightly oversize in this series of holes.

1. Basic hole size extremely consistent as evidence by the range measurements of the set. Range also is the predominant factor in determining hole shape for this set. A series of measurements taken at twenty-eight (28), thirty-two (32), forty-four (44), or fifty-two (52) locations within each hole, dependent upon the thickness of the hardware, were as follows:

Hole #	Range	Hole #	Range
1	0.000233"	11	0.000621"
2	0.000552"	12	0.000422"
3	0.000672"	13	0.003500"
4	0.000681"	14	0.003561"
5	0.000336"	15	0.003612"
6	0.000250"	16	0.004379"
7	0.000267"	17	0.004258"
8	0.000474"	18	0.000353"
9	0.000302"	19	0.000629"
10	0.000310"	20	0.000259"

2. Reference I.B. for hole location and Individual Hole Computer printouts. Eight holes, identified Hole #1, #5, #6, #7, #9, #10, #18 and #20 are virtually perfect hole specimens. Within this series, Hole #18 records the greatest range in measurements at 0.000353" and Hole #1, the least range spread, recorded at 0.000233". The aforenoted holes are representative of some of the varying hardware thicknesses encountered to accrue these holes and serve to demonstrate that personnel, tools and process are functioning harmoniously and in exemplary control.

3. Reference I.B. for hole location and Individual Hole Computer Printouts.
Hole #2, #11 and #19 are very good holes and well within the tolerance criterion established per Engineering; however, these are the first examples to demonstrate a barrelling feature inside the holes. Chip load, progressively building and followed by a gradual diminishing in the course of reaming is suggested as cause for barrelling. The feature is negligible at 0.000629", the maximum, existing on Hole #19.

4. Reference I.B. for hole location and Individual Hole Computer Printouts.
Hole #8 and #12 are only slightly departed from perfection with range measurements of 0.000474" and 0.000422" respectively. Slight side load is suggested for Hole #8 ovality and a chip gouge at levels 2 and 3 for Hole #12. Both are negligible and are not degrading to hole quality.
Holes #3 and #4 are very similar to Holes #8 and #12.

5. Reference I.B. for hole location and Individual Computer Printouts. Holes #13 through #17 have a common bellmouth enlargement characteristic at their entrance vicinity, plane levels #1 and #2. Holes #15, #16 and #17 are oversize very minutely with maximum values of 0.442845", 0.443379" and 0.443138" respectively recorded at their hole entry areas. Center seeking on the reaming pilot is the most probable cause for this slight entry flaw. It is considered negligible on analysis owing to magnitude, location and depth into the hole longitudinally.

   Hole #17 exhibits the largest dimension of this set at 0.443922", oversize at a value of 0.001422". This measurement also is considered no degradation to hole quality since it is a breakout spike occurring at the final exit plane and at only one point in the hole.

6. Reference to Individual Hole Histograms reveals a Normal Gausian Distribution and data populated about the 0.000438" and 0.000439" vicinities. This distribution offers evidence supporting a conclusion of process, tools and personnel operating in harmony.
Reference to the Executive Summary Histogram for this set discloses a relatively flat data distribution between 0.000438" and 0.000439". Multiple set-ups of varied hardware results in the aforementioned spread.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #17 and recorded at 0.002966" on the 0° - 90° axes. Ovality resulted from the breakout spur on the 0° axis. Reference to Individual Hole Computer Printouts. Holes #13 through #17 of this set reflect the following ovality values and locations:

Hole #	0° - 90° Axes	Plane #	45° - 135° Axes	Plane #
13	0.000655"	1	0.000793"	1
14	0.000793"	2	0.000620"	1
15	0.000759"	2	0.001328"	2
16	0.000629"	1	0.000870"	2
17	0.002965"	11	0.001362"	11

The above disclosure relates to the bellmouth enlargement discussed in Item III.A.5 and the spur at the exit plane at Hole #17.
Ovality measurements on all other holes of this set were very slight, ranging generally at 0.0002" and below.

C. Perpendicularity: Heavy fixturing assures perpendicularity of the holes with regard to the structure. Holes were checked by gaging with 10X magnification Azimuth/Angle Gaging Device and disclosed a 1° closed angle owing to the fuel shelf interface from which the measurement was taken. This angle is correct for the interface. Upon assembly of upper and lower halves of the bulkhead (fuel shelf sandwiched between the fittings), the final longitudinal axis of the hole with regard to the nut and head of the bolt is normal

(90^{o}) and no gaps are evident. Refer to paragraph II.A. for tooling compensation description.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: This characteristic has been discussed on affected holes of this set in the narrative per III.A.3.

F. Bellmouthing: This feature has been defined on affected holes of this set in the narrative per III.A.5.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of parts exhibited a very good interior hole sidewall texture. There were occasional shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

I. Surface Finish: All holes of this set exhibited a surface finish of "100AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-3

RANKING NUMBER 74*

HOLE SIZE: 0.251"/0.254"

I. OVERVIEW:

A. The structure is an all aluminum stack-up approximately 0.60" thick on the lower surface of an aircraft wing. The subject hole is sized per Process Criterion at 0.251"/0.254"; 0.0030" over the reamer size 0.2510".

An automated measuring system utilizing a thru-hole air-probe coupled to a Hewlett Package 9815A Programmable Calculator was used to accumulate, store and produce a Computer Statistical Printout of each hole of this set. The Computer Statistical Printouts of individual holes provide composite clues leading to disclosure of the geometric features of the holes related to their measurement profiles.

II. SUMMARY:

A. Twelve (12) holes were available in this structure for survey inspection. The sequence of production directed preliminary reaming of the holes to prepare them for cold working. A hand-held air powered drill motor driving a piloted tip reamer was employed to accomplish the task.

B. Reference Executive Summary for Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.253608" for the set of twelve (12) holes. This value, slightly below the high limit of the tolerance, is a result of a chronic bellmouth and/or taper characteristic throughout this series of holes. The geometric features of the holes are discussed in detail at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following:

* DRILL METHOD CODING: H-3 = Hand Held Drilling; Cold Worked Hand Held Reaming

1. Hand-held air powered drill motors for reaming.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.2470" (tip) and 0.2510" (shank).

2. Lack of assist tooling to stabilize the reaming operation.

3. Affect of reaming instability is apparent in the final hole.

III. CHARACTERISTICS:

A. Hole Size: 336 data measurements were accrued for the twelve (12) holes comprising this set. Reference, Executive Summary by Data Lot, discloses an arithmetical average of 0.253608", slightly below the Process High Limit Criterion.

Fifty percent (50%) of the holes in this lot exceeded the 0.2540" high limit criterion and are identified Holes #2, 6, 7, 10, 11 and #12.

1. Holes #6, 7 and #10, Reference Individual Hole Computer Printouts. The noted specimens are oversize the entire length of the holes and result from operator instability on the drill and long reamer length.

   The data spikes and oversize condition in the holes reflect operator side loading during the duty cycle of reaming.

2. Holes #2, 11 and #12. Reference Individual Hole Computer Printouts. These holes are oversize and bellmouthed and/or tapered which is the chronic geometric feature of this set.

   The characteristic is apparent at the start plane of reaming and gradually decreases in magnitude as depth in hole is acquired.

3. Holes #1 and #8 exhibit the bellmouth feature similar to item #2 above, but the measurements all are within the tolerance allowable and do not exceed the 0.2540" limit.

4. The bellmouth feature is the product of "center-seeking" of the reamer and insufficient assist tooling (drill plate with reamer guide bushing) to stabilize the reamer during its duty cycle.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #11 and disclosed a value of 0.001129" on the 0^{o} - 90^{o} axes at level 1. Ovality at this hole exceeded the Engineering tolerance criterion as a product of the bellmouth feature at the entrance plane of the reamer due to "center-seeking".

Ovality within itself did not exceed 0.001129" and the feature was less at all other holes in the set; therefore, ovality was not a cause for concern in this set. The bellmouth and/or taper precipitated the feature in all holes.

C. Perpendicularity: Several holes within the series were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. The holes were normal (90^{o}) to the longitudinal axis of the hole with regard to the outer surface of the wing structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analysis.

E. Barrelling: Non-existent as evidenced by profile analyses in all holes except Hole #10. This hole exhibits a feature roughly barrelled in characteristic and is the result of operator side load instability. Refer to narrative at par. III.A.1.

F. Bellmouthing: All holes are bellmouthed in association to their entrance plane characteristic. Refer to narrative at paragraph III.A.1 thru III.A.4.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited fair interior wall texture. Inspection was performed with Sight Pipes at 3X magnification. There were no chatter marks, scratches nor scoring in these holes; however, rifling was prolific throughout the set.

H. Burrs: There was no evidence of burrs in the stack-up of materials in the assembly.

I. Surface Finish: All holes of this set exhibited a surface finish of approximately 150AA. Optical surface comparator was used in this inspection. Surface was generally rougher than normal as a result of the rifling feature.

DRILL METHOD Q-2

RANKING NUMBER 75*

HOLE SIZE 0.3125"/0.3155"

I. <u>OVERVIEW:</u>

A. This set of production holes features drilling of a structure approximately 1.625" thick through one solid member.

The subject hole is sized by Engineering at 0.3125"/0.3155", for hi-strength blind fastener installation.

II. <u>SUMMARY:</u>

A. Twenty-nine (29) holes were available in this structure for survey inspection. The method of production was unique on this series of holes owing to the fact that two (2) hole drilling methods were employed as follows:

1. Holes #1 through #16 were produced by Quackenbush method; "one-shot" drilling to hole final size and <u>no</u> <u>reaming</u>.

2. Holes #17 through #29 were produced by Desoutter method; preliminary drilling to 19/64" hole diameter, followed by reaming to arrive at the final hole using a 0.3115", +0.002"/-0.000" reamer.

Inspection measurements were obtained via "thru-hole" air probe. Seventy-two (72) measurements were taken in <u>each</u> <u>hole</u>, at 0°-45°-90° and 135° axes, and at eighteen (18) plane levels within the hole. Excellent profile characteristics were achieved for reporting.

B. Reference Executive Summary by Data Lot. These holes disclose a measurement distribution whose arithmetical average is 0.313492" for the set of twenty-nine (29) holes.

1. The arithmetical average for Holes #1 through #16, produced by the Quackenbush Method, is 0.313596". This group of holes per Individual Computer Printout disclose a more desirable geometric profile and tolerance status than the holes produced by the Desoutter Method. Hole #2 is the only hole within the Quackenbush set disclosing an oversize condition. None of the Quackenbush holes were undersize.

2. The arithmetical average for Holes #17 through #29, produced via the Desoutter Method, which includes final reaming is 0.313341". Individual Computer Printout discloses a "rash" of undersize values residing in the Desoutter holes. Ten (10) of the twelve (12) hole total

* DRILL METHOD CODING: Q-2 = Quackenbush, Air Power Reamer, Mechanical 2 methods: #1-#16, Quack. one-shot. #17-29, Desoutter followed by reaming to achieve final hole size.

are affected by <u>undersize</u> dimensions. In addition, eight (8) of the Desoutter holes also reveal <u>oversize</u> conditions.

Details on the geometric features of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Tooling concepts are distinguishable in drilling results:

   a. Quackenbush method. Drilled holes and no reaming for holes identified #1 through #16.

   b. Desoutter method. Drilled preliminary holes followed by reaming for holes identified #17 through #29.

3. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

Quackenbush Method: Holes identified Hole #1 through Hole #16.

A. Hole Size: 1. One (1) hole, identified Hole #2 is the <u>only</u> specimen of the Quackenbush Method disclosing an <u>oversize</u> condition and there are <u>no undersize</u> holes produced via this method. The general geometric profile of the Quackenbush holes are superior to the Desoutter reamed holes.

a. Hole #2 exhibits a shallow, spiralled, operator induced side-load gouge. It starts at plane level #13 on the 0° axis and is recorded at 0.315621". The gouge extends 3/16" in length, then shifts to its 45° axis where it accumulates an additional 3/16" in length and achieves its maximum dimension, 0.315948", at plane level #17. At the exit plane, level #18, the hole is back in tolerance.

Reference to Individual Computer Printout for Hole #2. The Profile Presentation discloses the flaw area at its 0° axis on plane levels #13 through #17. Cause of this gouge is operator side loading induced as a result of handling the power head while the drill is in its duty cycle.

b. There were no undersize holes. The Quackenbush holes were very good on profile considering the extremely long engagement of the drill duty cycle. The following are examples of the total spread (range of measurements) taken at seventy-two (72) locations within individual holes:

Hole #	Range of data	Comment
3	0.000707"	Generally very good profiles with only slight deviations due to side-loading and chip load variation.
4	0.000966"	
7	0.000905"	
14	0.000836"	
15	0.000931"	
16	0.000681"	
1	0.001939"	Generally very good; slight side load deviations and predominantly along one axis.
5	0.001216"	
8	0.001034"	
9	0.001052"	
11	0.001164"	
12	0.001293	
2	0.0003707"	Generally heavier side loads and affecting two axes of orientation.
6	0.0002293"	
10	0.002207"	

All of the holes above, except Hole #2, are acceptable to the established Engineering Criterion. Hole #2 is discussed separately under item III. A. 1. a.

Desoutter Method: Holes identified Hole #17 through Hole #29.

A. Hole Size: 1. Eight (8) holes exhibit oversize conditions.

a. Hole #17 oversize at a depth of 0.35" to 0.60" along the 0° -45° axes of orientation. The maximum recorded defect, 0.316310", is located at plane #7. Individual Hole Computer Printout suggests the cause as side loading brought about by operator handling (weight moment) on the drill during its duty cycle. Owing to this bending moment, the drill translates to enlarging the hole.

b. Hole #18. This hole position was directly adjacent to Hole #17. It exhibits similar spurs of oversize at nearly the same depth and along its 0° axis. The maximum recorded defect, 0.315957", is located at plane #8. Cause is identical to Hole #17.

c. Hole #19 exhibits an oversize lobe on its 45° axis reference at a depth of 0.70" inside the hole and is continuously oversize until it exits the structure. The oversize, 0.316414", begins at plane #11 and with slightly varying magnitude, continues to the end of the hole. The affect of side loading is also apparent (but <u>not</u> out of tolerance) along the 0° axis.

d. Hole #20. This hole position was directly adjacent to Hole #19. It exhibits identical oversize lobe except that it occurs along the 0° axis and its adjacent 135° axis. The start of the oversize begins at a depth of 0.30" into the hole and continues at varying magnitude to the exit plane of the hole.

The affect of side loading is apparent along the 0°-135° axes.

e. Hole #23. This hole, the <u>worst</u> of the set, presents a spiralled oversize meandering between the 0° through 90° axes as depth in the hole is acquired from plane #1 through plane #11. A barrelling condition, oversize in <u>all</u> four (4) axes, is apparent at planes #8 through #11.

The largest oversize dimension for this set occurs at plane #9 (0.316888") on the 0° axis. Side loads in the 0°-45° axes are predominant on this hole.

f. Hole #24 exhibits only one (1) spot out of tolerance. It occurs at plane #10 and is recorded at o.315526" on the 45° axis. This spur is a very insignificant in itself; however, study of the Hole Profile discloses that <u>enlargement</u> is occurring in the vicinity of planes 10 through 12.

g. Holes #25 and #27 reveal similar spikes to that of Hole #24.

2. Ten (10) undersize holes via Desoutter Method. The undersize conditions are the result of the 0.3115" reamer size.

a. Hole #27 exhibits the greatest amount of undersize by record of 0.311457" which occurs at the entrance of the hole and gradually enlarges with depth. Again, at plane #12, an enlarged, out of tolerance condition is present owing most

probably to chip load binding since <u>all axes</u> are affected.

b. The remaining undersize holes, identified as Holes #19, #21, #22, #23, #24, #25, #26, #28 and #29 are characteristically identical. They are undersize at the start of drilling/reaming and acquire a size approaching the acceptable limits (0.3125"/0.3155") as depth is achieved. The affect of operator side loading is also a common characteristic.

NOTE: The characteristics discussed at B. through I. in the following text is common to both methods of production unless otherwise stated.

B. Ovality: Hole #19 revealed a maximum ovality within the set and was recorded at a magnitude of 0.003698" at Level #17 on the 45^{o}-135^{o} axes. Ovality was induced by operator side loads as described in Desoutter Method, item III. A. 1. a. and III. A. 1. c.

On the holes produced by the Desoutter Method, ovality was affected by the oversize conditions reported for these holes.

The Quackenbush Method produced holes whose ovality feature was much less severe. Hole #2, the only oversize hole of this method disclosed a maximum ovality at 0.002009" at the 0^{o}-90^{o} axes and occurring at plane level #13. This is the area <u>affected</u> by the side load gouging.

The remainder of the Quackenbush holes recorded values as low as 0.000259" for Hole #2 through a maximum of 0.001914" at Hole #13. Ovality was not a cause for concern on this series of holes.

C. Perpendicularity: Fixturing assures perpendicularity of the holes with regard to the structure. Several holes of this series were large enough to permit gaging using the 10X magnification Azimuth/Angle Gaging Device. These holes were verified to be normal to the longitudinal axis of the hole with regard to the drilled/reamed structure.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Hole #3 exhibits an extremely shallow barrelling. Hole #13 provides a general profile of barrelling to a slight degree. It is erratic and most probably the result of chip loading on this hole since the barrelling enlargement is evident in all axes. Some evidence of side loading is also apparent; reference spikes in the profile data.

F. Bellmouthing: Evident in subtle amounts as indicated by Holes #1, #15, #25 and #26. The condition is minor and in all cases does <u>not</u> <u>exceed</u> the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. Rifling generally was apparent where sideload gouging resulted in the oversize conditions. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through one solid structural member and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny except where gouging via side loads was apparent.

DRILL METHOD S-2

RANKING NUMBER 76*

HOLE SIZE: 0.3090"/0.3110"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of an Aircraft Wing Splice Installation. The structure is the left hand wing top and bottom panels. The area for hole survey is the inboard row of 5/16" fasteners identified WZ 10 (HL19PB; HiLok Flush Bolts), located 1.86" inboard from the toe of the main splice forging. The assembly is approximately 0.75" thick in the area being surveyed and the subject holes are sized per planning at 0.3090"/0.3110".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for survey. The method of production featured preliminary Spacematic drilling of the structure followed by hand reaming of the holes to achieve final Engineering size. Measurement data was accumulated at forty-four (44) locations within each hole via "thru-hole" air probe.

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.310470" for the set of twenty-nine (29) holes. Normally the aforenoted average would be considered an acceptable feature since it resides within the parameter of the high limit of the Engineering tolerance range; however, there is an adverse inherent "bellmouth" characteristic throughout this series of holes.

Owing to the bellmouth feature, 79% of the holes of this set exceed the 0.3110" high limit.

Specific discussion on the geometric characteristics of the holes, including the exception above, are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

* DRILL METHOD CODING: S-2 = Spacematic, Hand-held reaming.

Spacematic, air driven power unit w/hand reaming.

1. Custom designed fixturing ensures interchangeability and location reliability.

2. Spacematic, air driven power unit produces preliminary holes prior to hand reaming to their final Engineering size.

3. Reaming is accomplished via hand-held air powered drill motor driving a piloted reamer to acquired final hole size at 0.3090"/0.3110".

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 1276 data measurements were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set, 0.310470", is deceptive in the face of an inherent bellmouth feature exiting on the holes.

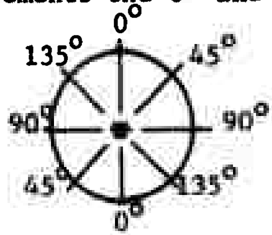
1. Reference Individual Hole Computer Printouts.
The bellmouth feature exists at the entrance plane of the holes which is the outer surface of the wing in regard to the direction of drilling and proceeds at a diminishing taper rate until an in-tolerance mode is achieved. Generally, this condition is not acquired until the operator is 30% or more through the assembly stack.
Note: Holes #1 through #22 are on L.H. Bottom Panel.
Holes #23 through #29 are on L.H. Top Panel.

2. Reference Individual Hole Computer Printouts for Holes #1,#3,#4 and #7 through #15.
The above noted twelve (12) holes are oversized in a bellmouth mode on <u>all axes of measurement</u> and diminish at a relatively consistent rate as depth in the hole is achieved.
The condition is suggestive of chatter (center-seeking) of the reamer pilot since <u>all axes</u> are equally affected on magnitude.
Reference note #1 on page 4.

3. Reference Individual Hole Computer Printouts for Holes #16,#27 and #29.
These holes exhibit the affect of operator side loading during the hand reaming operation. Operator instability on hand operations is distinguished by hole enlargement along the axis/or adjacent axes where the load was applied as illustrated by the Computer Profile Data:

Hole #	Axis/Axes Affected
16	0^{o}-45^{o}-90^{o}
27	0^{o}-135^{o}
29	90^{o}-135^{o}

Note: On axis oriented measurements the 0^{o} and 135^{o} are adjacent.



4. Reference Executive Summary Histogram. The data profile for this set populates the entire tolerance/oversize zones and features various spikes. The data is indicative of the hole variations experienced via the bellmouth feature discussed in the aforementioned text. Additionally, there is an inherent instability associated with hand-held drill/reaming operations when assist tooling is not employed to help control alignment.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #27 and discloses a value of 0.003379" at plane level #11 on the 45^{o}-135^{o} axes. Enlargement ovality at this plane of measurements results from side loads induced via operator instability during reaming resulting in enlargement along the 135^{o} axis. The affect of operator side loading has been discussed in the narrative per item III.A.3.

Ovality is affected by the taper and operator side load on these holes and its magnitude a function of the oversize conditions.

C. Perpendicularity: Absence of an appropriate plug to accommodate this hole size would not permit inspection via the Azimuth/ Angle Gaging Device; therefore, verification of perpendicularity was accomplished by sample fastener installation and head gap inspected. The longitudinal axis of the holes is normal (90^{o}) to the skin outer surface and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None-existent as evidenced by profile analyses.

F. Bellmouthing: Evident throughout this set in varying amounts as indicated per item III.A.1. through item III.A.3. The holes of this group exhibit the bellmouth/taper condition at their entrance plane of drilling and reaming. Cause has been related to "center-seeking" resulting from hand reaming instability.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited a very good interior wall texture. There was only very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled through stack-up of skin panel, shim and splice forging, was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 77 *

HOLE SIZE: 0.247"/0.250"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Fuselage Side Panel to Frame Structure. The structure is aluminum skin and frame whose combined thickness is approximately 0.250" at the area to be drilled and reamed. The hole being inspected is sized at 0.247"/ 0.250" by Engineering. Owing to this structure thickness combination only four (4) measurements (one plane level) was taken.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The material, a combination of aluminum (skin to frame), was inspected by "thru-hole" air probe. Measurements were taken by air probe penetration from outside the structure and progressing inboard toward the frame. The method for drill and reaming was hand held air motor and hand held guide bushing accessory tooling.

The computer data Statistical Printout for this series of holes provides a composite traceable to the following for the production of good holes:

1. Custom fixturing was not required to locate the holes.

2. Hand held drill/reaming method and accessories were adequate to produce a good set of holes.

3. Planning is excellent for inspection traceability on holes.

* DRILL METHOD CODING: H-2 = Hand-held Drill and Reamer

Hand-held drill/reaming and accessories.

II. A. (Continued)

4. Good tooling on a planned periodic refurbish program, coupled with the mandatory requirement for technician to draw new and/or currently refurbished/reinspected drills and reamers from production tool cribs for use on the job is evident in product quality.

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. CHARACTERISTICS:

A. Hole Size: Twenty (20) of the holes were within the allowable Engineering criterion of 0.247"/0.250". Holes are individually excellent on size. Measurements taken at 4 locations within each hole yield an average value of 0.248960". Hole #4 only was oversize in the 0^{o}-90^{o} axes and also in the 45^{o}-135^{o} axes. All other Hole #4 measurements disclose an oversize condition of 0.001638". The cause for oversize and ovality is construed to be the result of instability on the hand held bushing guide during reaming.

The trend in measurements in indicative of tooling producing ideal holes since the yield of all measurements provides an average size of 0.248960", tending toward the midpoint of the tolerance spread.

B. Ovality: Maximum recorded ovality within the set was 0.002233" at Hole #5. Individual holes within this set (4 measurements per hole) ranged to as low as 0.000000" at Hole #11.

Ovality at Holes #1, 2, 3, 4, 6, 7, 8 and 24 was very slight. Maximum ovality 0.002198" occurred at Hole #24. The least oval condition of these listed

III. B. (Continued)

holes occurred at Hole #4 and was recorded at 0.000828" on the 0^{o}-90^{o} axes and 0.0000733" at the 45^{o}-135^{o} axes.

The cause for the slight ovality within this set of holes is considered the result of instability on the hand held bushing guide for reaming. Ovality is predominately at the start (entrance) to the hole, and is very slight. Refer to Computer Printout.

C. Perpendicularity: Material thickness combination was too thin to obtain an accurate perpendicularity measurement. Fastener insertion visual check was satisfactory.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: None evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed by hand method and was deburred satisfactorily in the normal process plan

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD Q-1

RANKING NUMBER 78 *

HOLE SIZE: **

**0.248"/0.250" for Holes #3 thru #22
**0.250"/0.254" for Holes #1, 2; 23 thru #29

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of a Floor Beam. The structure is a heavy aluminum "Hat Section" of varying thickness. Holes of the set were sized by Engineering at 0.248"/0.250" and 0.250"/ 0.254". Inspection was performed using a "thru-hole" air probe with results automatically recorded for computer printout. Twenty-nine (29) holes were surveyed in this set.

II. SUMMARY:

A. A processing problem was discovered during the measurement inspection of this set of holes. The Host Facility Escort was on the scene and witnessed the discovery of the characteristic of tapered holes and the pursuit to conclusion of the cause. Details of the specific problem of tapered holes is discussed in paragraph III.A.

The computer data Statistical Printout for this series of holes provides a composite traceable to the following for the production of the holes:

1. Custom fixturing was required to locate the holes for drilling.

2. Quackenbush and/or Desoutter manual rack feed drilling method and accessories were used to produce these holes.

3. Hand held air motor reaming method for reaming only.

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand-held Air Power Reamer.
Quackenbush, Desoutter manual rack feed drilling and accessories.
Hand-held air motor reaming method.

II. A. (Continued)

Note: Method inadequate to produce acceptable holes in the 0.248"/0.250" size. The objectionable characteristic also was present in the 0.250"/0.254" size but remained within Engineering tolerance. Item is discussed in paragraph III.A.

4. Planning is excellent for inspection traceability on holes.

5. Planned periodic refurbish program, coupled with the mandatory requirement for technician to draw new and/or currently refurbished/reinspected drills and reamers from production tool cribs for use on the job in all probability prevented item #3 above from escalating to a more serious problem.

6. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

Note: The technician responsible for production of these holes was truly concerned over the fact that his job station showed a consistent oversize hole condition. He expressed a desire to pursue corrective action liaison with tooling/supervisory personnel to eliminate the problem.

III. CHARACTERISTICS:

A. Hole Size: 0.248"/0.250" is effective for Hole #3 thru #22 inclusive. All except Holes #10, #13, #14 and #15 exceeded the Engineering size criterion in varying amounts to a maximum of 0.003819" at Hole #18. Reference to the Computer Printout discloses a "cone effect", constant in characteristic from the last plane of measurements (largest readings) toward the first measurement plane (smallest readings) of these holes. Upon discovery of this trend

III. A. (Continued)

the Hole Survey was momentarily stopped to pursue an investigation for probable cause of the taper phenomenon. The investigation concluded as follows:

1. The operator drilled this set of holes from a custom designed fixture specific for this structure.

2. Drilling was accomplished per paragraph II.A.2 method. The face of the part subject to the drill first contact (entry point) was opposite from the direction that air gage measurements were taken. Therefore; on the data printout for the hole profile the strip chart bottom plane is the entrance plane for actual drilling and subsequent reaming.

3. The part after drilling is removed from the fixture and hand reamed by hand-held air motor.

4. Reaming was performed without aid of accessory tooling and the part's drilled hole acting as the reamer alignment guide. Subtle movement by the technician resulted in out of tolerance tapered holes. Refer to the Computer Printout for specific details on actual measurements per hole.

Hole Size: 0.250"/0.254"

The same taper characteristic inherent in the 0.248"/0.250" persists in the larger holes. Owing to the greatest tolerance spread, the 0.250"/0.254" holes are within Engineering criterion. The taper runs to varying depths in excess of one half inch.

III. (Continued)

B. Ovality: Maximum recorded ovality within the set was 0.000319" at hole #18. Individual holes within this set (generally 40 measurements per hole) ranged to as low as 0.000086" at Hole #10.

The cause for the slight ovality within this set of holes is considered the result of operator side loads during hand held power drill in the reaming operation.

C. Perpendicularity: Assured by custom fixturing to 0° after drill. Parts after free hand reaming within $\frac{1}{2}^{\circ}$ Engineering tolerance.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: All holes contain bellmouth (taper) evident as indicated by the profile analyses.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through one solid flange and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD S-1

RANKING NUMBER 79 *

HOLE SIZE: 0.1860"/0.1900"

I. OVERVIEW:

A. This set of production holes features drilling of the Rear Spar Installation, Lower Surface, between Wing Stations 66.0" and 90.0", on the Spar Forward Leg. The structure is an all aluminum stack consisting of the rear spar flange and the lower skin panel. The approximate thickness in the area to be surveyed is 0.625". The subject hole is sized by Engineering at 0.1860"/ 0.1900" for installation of Hi-Lok flush head bolts.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production was planned for Spacematic drill; however, owing to inaccessibility in the assembly fixture the following method was used:

Holes #1 through #9......Behind pole.....Hand drilled
Holes #10 through #17....accessible......Spacematic drilled
Holes #18 through #26....Behind pole.....Hand drilled
Holes #27 through #29....accessible......Spacematic drilled

The hand drilling operations utilized a hand-held guide bushing with a 5/8" engagement length.

Spacematic utilized normal tooling referenced in planning. Freon coolant was used in both drilling methods as lubrication fluid.

Inspection measurements were obtained by "thru-hole" air probe.

* DRILL METHOD CODING: S-1 = Spacematic, One-shot, No reaming.

Spacematic drilled and hand drilled.

II. (Continued)

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.187980" for the set of twenty-nine (29) holes. This value is a very good feature since it resides at the mid-point vicinity of the Engineering tolerance range. Two (2) holes, identified Hole #17 and #27, are oversize approximately at the midpoint area of the length of the hole. All other holes of this set meet the criterion established by Engineering. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Spacematic, air powered drill and accessory tooling produces generally good "one-shot" holes at assembly.

3. Hand-held, air powered drill and hand-held guide bushing used on this set only produced holes of good quality.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements.

III. CHARACTERISTICS:

A. Hole Size: 812 data entries were accrued for the series of twenty-nine (29) holes. The arithmetical average for the set is 0.187980" as evidenced per the Executive Summary by Data Lot.

1. Holes #17 and #27 are the only holes of this set exhibiting an oversize condition. Both of these holes were produced by the Spacematic method. Both holes are the first accessible following an interference

III. A. 1. (Continued)

condition experienced on the fixture. They have similar features of hole enlargement at all axes of measurement and are somewhat barrelled. Chip load is suggested as cause for enlargement on Hole #17 to a maximum recorded value of 0.000571" at plane level #4 on its 0^{o} axis. Review of the Individual Profile for Hole #17 discloses the slight oversize to be nearly the full length of the hole.

Hole #27 is very similar to Hole #17. Although the aforenoted holes were the only specimens to exceed the Engineering tolerance, scrutiny of the measurement patterns of <u>all holes produced via the</u> Spacematic drill are consistently <u>larger</u> than the hand-drilled holes.

2. Technique comparison via Individual Computer Printout reveal the following measurement range:

Hand Drilled	Range	Spacematic	Range
#1	0.000820"	#10	0.002112"
#2	0.000371"	#11	0.001103"
#3	0.000422"	#12	0.002026"
#4	0.000724"	#13	0.002784"
#5	0.000560"	#14	0.002897"
#6	0.001034"	#15	0.002276"
#7	0.000767"	#16	0.000991"
#8	0.000853"	#17*	0.002442"
#9	0.000595"	#27*	0.003345"
#18	0.000647"	#28	0.002095"
#19	0.000543"	#29	0.000942"
#20	0.000871"		
#21	0.001042"		
#22	0.000707"		
#23	0.000483"		

III. A. 2. (Continued)

Hand Drilled	Range
#24	
#24	0.000629"
#25	0.000793"
#26	0.000515"

Note: The only oversize holes of the set set are identified (*) above. Hand drilling is consistently smaller than the Spacematic drilled holes. Most probable cause for this feature is a closer fit between the drill bit and drill bushing on the hand drilled holes. Close tolerance on the bushing prevented wobble. At the same time, the hand-drilled holes reveal a taper or bellmouth (very minute) most consistently at their exit planes (see Holes #3, #4, #5, #6, #9 #18, #19, #20) whereas the Spacematic holes are generally larger with the bellmouth/taper feature at their entrance planes of drilling. Slight wobble is suggested on the spacematic and chip load beginning to build up at the exit planes for the hand drilled holes.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #6 and recorded at 0.000914" at Level #1 on the 45^{o}-135^{o} axes.

Ovality was not a cause for concern on this set. Reference to Individual Hole Computer Printout discloses all holes to be extremely good on the ovality measurements. None of the holes exceeded the Engineering Criterion.

III. (Continued)

C. Perpendicularity: Hole size, on the low side of the tolerance, would not permit inspection via the Angle/Azimuth Gaging Device, therefore verification of perpendicularity was verified by sample fastener installation and head gap inspected. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering Criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Hole #27 Individual Profile reveals a very subtle barrelling feature. Drill wobble is suspected as the cause for the geometric configuration of this hole. The feature is subject for engineering review with Hole #17, also slightly oversize.

F. Bellmouthing: Evident in very subtle amounts as indicated by Holes referenced in the note at item III.A.2. Various other holes of this set exhibit the same condition at their entrance plane of drilling; however, none of the conditions exceed the allowable Engineering tolerance.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

III. (Continued)

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-3

RANKING NUMBER 80*

HOLE SIZE: 0.245"/0.248"

I. OVERVIEW

A. An automated measuring system utilizing a thru-hole air-probe coupled to a Hewlett Packard 9815A Programmable Calculator was used to accumulate, store and produce a Computer Statistical Printout of each hole of this set. The Computer Statistical Printouts of individual holes provide composite clues leading to disclosure of the geometric features of the holes related to their measurement profiles.

II. SUMMARY

A. Eighteen (18) holes were available in the noted aircraft for survey inspection on a non-interference basis. Only the manufacturer installed fasteners were removed and the holes, in a virgin condition, were measured and inspected. Interference fit of the initial fastener installation and removal resulted in splayed material abrasion lines running longitudinal to the holes along their sidewalls. Occasional shallow angle rifling not in excess of the 125AA machine finish was apparent in several holes. Clamp-up was good owing to the proximity of installed adjacent fasteners remaining in the structure.

B. Tolerance criterion of 0.245000"/0.248000" was arbitrarily established as measurement limits for these holes for purpose of collecting computer data via thru-hole airprobe. Depending on structure thickness, a minimum of (20) and a maximum of twenty-eight (28) measurement data locations were accrued for each hole to establish profile characteristics of the specimens and reveal their geometric features.

* DRILL METHOD CODING: H-3 Hand Held Drilling, Cold Worked
Hand Held Reaming

III. CHARACTERISTICS:

A. Hole Size: 440 data measurements were accrued for the series of eighteen (18) holes. Reference, Executive Summary by Data Lot discloses an arithmetical average of 0.249632" for this set. This is an acceptable feature for these holes since the manufacturers design criterion is 0.2460"/0.2500" for the one quarter inch size Flush Hi-Lok Fasteners.

All of the holes except Hole #15 are considered acceptable per data analysis. However, there is a very minute and shallow bellmouth condition at the entrance plane of the holes. Reference to Individual Hole Computer Profile Printout reveals a magnitude generally less than 0.001" and disappearing after 0.125"/0.187" depth in hole is achieved.

There is also a classifying characteristic evident in the data by the Individual Hole Computer Printouts as follows:

1. Holes #1 thru #8; all from the aircraft center spar area, are very slightly smaller in diameter than Holes #9 thru #18, which are from another aircraft along its front spar.

2. Comparison of the data reveals the entire measurement population for Holes #1 thru #8 to reside between 0.247655" (lowest) to 0.249534" (highest). Generally, the holes run 0.248"/0.249" for size.

3. Analysis of the data for Holes #9 thru #18 reveal holes of slightly larger configuration and tend to 0.249"/0.250" for size.

4. The very minute bellmouth feature inherent in the set is located at the entrance plane immediately below the countersink on Holes #1, 2, 5, 6, 7, 8, 10, 14, 15, 16 and 18. The most probably cause for this condition is "center-seeking" of the drill/reamer on initial production. It is very minor and disappears as depth in hole is achieved.

5. Hole #15, the largest of the set with a maximum reading of 0.252147", again is attributed to the bellmouth feature.

6. Chip build-up resulted in a slight bell-mouth at the exit vicinity of Holes #9, 12 and 18.

7. Holes #3, 4 #13 and #17 exhibit chip spikes that are of no consequence to the overall quality of the holes since they are 0.0005" or less in magnitude.

8. This is a good series of holes. The minor features discussed in the aforementioned text serves to apprize the reader of the ability of the computer to construct a pictorial geometric replica of the holes using very minute measurement differences. The range variation in measurements from largest to smallest reading exhibited by the holes of this set are as follows:

Hole #	Range	Hole #	Range
1	0.001388"	9	0.000603"
2	0.000905"	10	0.000914"
3	0.000578"	11	0.001026"
4	0.000457"	12	0.000940"
5	0.000724"	13	0.000974"
6	0.001121"	14	0.002086"
7	0.001371"	15	0.001845"
8	0.000940"	16	0.000819"
		17	0.001948"
		18	0.000966"

B. Ovality: Maximum recorded ovality within the set occurred at Hole #7 and discloses a value of 0.000914" on the $0^{\circ} - 90^{\circ}$ axes. Ovality is slight and does not exceed the Engineering tolerance criterion and is the product of the bellmouth feature in this hole.

Ovality was not a cause for concern on this set. Reference to the Individual Hole Computer Printout discloses all holes to be extremely good on ovality measurements (generally less than 0.0005"). None of the holes of this set exceeded the Engineering criterion.

C. Perpendicularity: Hole size, below 0.250" diameter, would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished via inspection of the head to countersink nesting of other fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Non-existent as evidenced by profile analyses.

F. Bellmouthing: Evident in very minute and subtle amounts as indicated by holes references in III.A. and III.A.4 narrative.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited some abrasion lines running longitudinal to the holes and along their sidewalls and occasional shallow angle rifling not in excess of the 125 AA machine finish. Inspection was performed via Sight Pipe at 3X magnification. There were no chatter marks nor vertical sharp scoring in these holes.

H. Burrs: There was no evidence of burrs in the stack-up of materials in the assembly.

I. Surface Finish: All holes of this set exhibited a surface finish of 125 AA or better. Optical surface comparator was used in this inspection. Surfaces, except for the abrasion caused via interference fit of the fastener, was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 81*

HOLE SIZE 0.190"/0.193"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Tail Skin to Frame Structure. The holes were sized at 0.190"/0.193" by Engineering.

II. SUMMARY:

A. The absolute values on the Computer Printout, representing the hole size for this set, is of questionable creditability. Upon visual inspection of the holes after air gage measurements were complete the following was evident:

1. Sealant, gray in color and of rubbery consistency, had migrated from the skin to frame faying surfaces into the holes.

2. The hole sidewalls exhibited a dull gray film where the reamer flutes had "trowelled" the sealant onto the hole sidewalls. Additionally, a slight "bead" of sealant impinged on several holes in varying amounts from 20° through approximately 180° of the faying surface inside circumference. Except for the sizing creditability, all other characteristics are valid data elements and are reported in paragraph III.

B. On subsequent sets of holes the Survey Team used cloth and swabs to clear away sealant and foreign materials prior to engaging in actual air probe measurements.

C. The computer data Statistical Printout for this series of holes provides a composite traceable to the following:

1. Custom fixturing was not required to locate the holes.

2. Hand held drill/reaming method and accessories were adequate to produce a good set of holes.

3. Planning is excellent for inspection traceability on holes.

4. Hand held drill/reaming bushing overriding a skin thickness offset resulted in 1° angle on hole perpendicularity.

* DRILL METHOD CODING: H-2 = Hand-held Drill and Ream. Hand-held drill/reaming and accessories were adequate.

C. (Continued)

5. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced.

III. CHARACTERISTICS:

A. Hole size: Virtually all of the holes of this set indicated an undersize condition at the entrance plane and extending several levels down inside the hole. The measurements are undersize generally by only tenths of thousandths in areas where the sealant is spread as a "film". Where the air probe encounters the "bead" of sealant the measurement is in error as much as 0.001" to 0.004043" as indicative of Hole #1. Sealant impingement is the cause for the undersize measurements as stated in paragraph II.A.1 and .2.

Five (5) holes, identified #2, #6, #7, #15 and #29 exhibited oversize measurements. Holes #2, #6 and #7 were oversize at the exit (frame outlet) side of the holes. Subtle movement by the operator coupled with relative instability of the reamer guide bushing is the most probable cause of the slightly oversize readings. The maximum oversize readings for these holes were 0.193560", Hole #2; 0.193190", Hole #6 and 0.193552, Hole #7.

Hole #15, oversize only at two (2) of the four exit plane measurements is most probably reamer breakout "grab" and is not cause for considering this hole as oversize.

Hole #29 is a consistent six ten-thousandths (0.0006") oversize. Most probable cause for oversize on this hole is operator position. The noted hole was at the end of the drill pattern and position on the fixture was not as comfortable using hand-held reamer powerhead and hand-held guide bushing.

NOTE: During the process of drill/reaming, the operator performed a self check of his work by plug gage inspection. He used 0.1900"/0.1930" Blade Plug Gages. We are assured that the holes of this set are <u>not undersize</u> as referenced per Computer Printout owing to witnessing the mechanical blade-gage check by the operator. The oversize conditions reported for Holes #2, #6, #7 and #15 is not a detectable characteristic using the blade-gages and inspection from the direction that gaging was performed. The oversize condition of these holes was very minute and at the exit side of a relatively thick material stack-up.

B. Ovality: Maximum recorded ovality within the set was 0.002940" at Hole #1. This measurement is discounted owing to the fact that the maximum ovality occurred at level #1 in the hole which in reality is the extruded sealant causing an obvious error. Ovality is not a characteristic for concern on this series of holes owing to the sealant "film" described in paragraph II.A.1 and .2.

C. Perpendicularity: All of the holes running vertically along the frame exhibited a 1° angle on perpendicularity. Cause for the 1° on alignment was the result of the drill/reamer guide bushing overriding a thicker skin (approximately 0.030" offset) forward of the subject holes. The guide bushing base "bridged" the skin offset resulting in a 1° angle for drilling/reaming. Measurement for perpendicularity was performed with the 10X magnification Azimuth/Angle Gaging Device with magnetically coupled Standoff Bushing to avoid the skin offset.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: Slight as indicated by the profile analyses and most generally occurring at the exit of the holes.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through a stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection.

DRILL METHOD Q-1

RANKING NUMBER 82 *

HOLE SIZE 0.375"/0.379"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Fuselage Rear Spar Fitting. The structure is aluminum forgings (7075-T6 material) whose finished machined thickness is 0.626". The subject hole is sized at 0.375"/0.379" by Engineering.

II. SUMMARY:

A. Twenty-nine (29) holes were available to provide the required sample size for the survey.

The method of production employed custom fixturing to assure hole location. Holes were drilled by Quackenbush air powered drill with auomatic feed. Reaming was accomplished in the fixture by hand-held air feed drill motor powering a piloted reamer to obtain final hole sizing. Inspection measurements were obtained by "thru-hole" air probe.

B. All of the holes for this set except one (1) are well within the tolerance spread established by Engineering and average overall at the low point range of the tolerance. Reference to the "Executive Summary by Data Lot" reveals the average hole size to be 0.376531", a desirable feature since the low to high limit criterion is 0.375000"/0.379000" respectively. The specific characteristics for these holes are discussed in detail at paragraph III. along with Hole #13, the only oversize hole whose measurement range is 0.377888"/0.379500".

C. The computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand held Air Power Reamer

Quackenbush, air powered drill w/auto. feed. Reaming w/hand-held air feed drill.

II. C. (Continued)

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush drill method and accessories producing good holes.

3. Hand held air powered drill motor utilizing a piloted reamer produces good final sizing of this set of holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: The holes of this set exhibit a characteristic "seeking" followed by the deeper penetration, the better the holes become on size measurements. The assembly stacking in the drill/ream fixture results in a very deep hole considering the spar forward cap, spar web, aft cap and then the forward and aft wing attach fittings. These combined thicknesses result in a hole depth exceeding two (2) inches. The assembly was at a disassembled stage when subjected to the survey inspection by "thru-hole" air probe. The following is evident.

NOTE: Only the -1 through -4 fittings were inspected on this lot from a disassembled spar.

1. Holes #1 through #8 are common to <u>one</u> (1) forging. The measurement population per Individual Histogram is clustered between the low-limit tolerance (0.375000"/0.376000") and the shape of the holes per profile analyses disclose them to be largest at the <u>entrance plane</u> (first level of measurements on the computer printout); then, progressing relatively

III. A. 1. (Continued)

constant to the smallest hole measurements at the exit plane of the fitting.

The "tapering" phenomenon results from slight side loads induced by the operator during reaming and first contact "seeking" of the reamer into the hole. Holes #1, 3, 4, 6 & 7 reveal a spur enlargement at the exit plane or one (1) plane prior to reamer exit of the hole. This spur is suggestive of a new starting chip from the web gouging the fitting as it seeks an exit path.

2. Holes #9 through #16 are common to one (1) forging. The measurement population in this part tends toward the high limit of the tolerance (0.378000"/ 0.379000"). Exceptions are Holes #9 and #10 that favor 0.37700", but are drifting toward the high limit. The holes in this forging also are largest near the entrance plane of the part and tend to get smaller as they approach the exit plane. Operator side loading during the reaming operation accounts for the barrelling interior as exhibited by Holes #9 thru #12 and #14 thru #16. Hole #13 reveals a consistent straight taper after an initial "start-up" side load occurring at level #2 in the hole.

   Absence of the spur phenomenon at or near the exit of the hole is most probably the result of a tighter clamp-up in the fixture and consistent chip follow up on exiting the hole.

3. Holes #17 through #24 are similar in characteristics to those of Holes #1 through #8 except that the forging was rotated 180°; thus, the measurement

III. A. 3. (Continued)

pattern of these holes and the profile analyses appear to be reversed to those of Holes #1 through #8. Reference Holes #17 and #20 through #24 for verification. Holes #18 and #19 are typical of side loading induced after reaming had begun and became better on size with depth.

4. Holes #25 through #29 are similar to item #3 above. The forging was rotated 180° prior to performing air-probe measurement verification.

5. All of the holes of this set, except Hole #13, meet the Engineering tolerance. The fact that the entire tolerance band was represented in this series of holes suggests an operator induced cause for the measurement spread. Side loads by operator handling most probably resulted in the full utilization of the tolerance.

B. Ovality:

Maximum recorded ovality within the set occurred at Hole #28 and recorded at 0.001974" at Level #6 and 0.001897" at Level #7. Actually these measurement planes are the entrance of the reamer into the hole and the second level of measurements. See item #3 and #4 in paragraph III. A for explanation.

Ovality was induced by the hand-reaming process but presents no cause for concern since it generally is less than five tenths of a thousandth (0.0005") in magnitude overall. Holes #2, #3, #5, #26 and #28 recorded measurements in the vicinity of 0.001"; however, all ovality measurements are well below the Engineering tolerance allowables.

III. (Continued)

C. Perpendicularity: All holes within this set were normal to the longitudinal axis of the hole with regard to the machined face (interface surface). Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: Evident as indicated by the profile analyses typical of Holes #9 thru #12 and #14 thru #16.

F. Bellmouthing: Evident as indicated by the profile analyses and general characteristic of large entry and small exit measurements.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes was drilled and reamed through a laminated stack and was deburred satisfactorily in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 83 *

HOLE SIZE 0.2495"/0.2515"

I. OVERVIEW:

A. This set of production holes features double margin piloted tip drilling of the Cargo Door Hinge and Jamb Structure. The structure is a stainless steel predrilled hinge, aluminum jamb and frame gusset stack up. The stack up of structure is approximately .500" thick and incorporates a gray colored "rubbery" textured sealant material between faying surfaces at all layup interfaces. The subject hole is sized by Engineering at 0.2495"/0.2515" for Huck-Bolt Fastener installations.

Hole survey measurements were obtained using a "thru-hole" air probe coupled to an Automated Computer System for data storage and recovery.

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production incorporated predrilled, installed hinge to ensure basic hole locations and interchangeability. A hand-held, air powered, drill motor driving a double-margin piloted tip drill was employed to obtain the preliminary hole using the steel hinge as a drill guide. A hand-held, air powered, drill motor driving a DJ-380 (0.2495") special piloted reamer was directed per planning to obtain the finalized hole per Engineering requirements.

An error was discovered upon starting of the hole measurement operations using the air probe and computer recovery data. The holes were grossly oversize. Measurements for this series were taken at the request of the Host Facility Escort for the purpose of Engineering information concerning dispositioning action. Investigation disclosed that an error had been committed whereupon an oversized piloted reamer had inadvertently been used for the final reaming. Measurement operations were resumed with results as follows.

B. Reference to the "Executive Summary by Data Lot" reveals the arithmetical average for hole size to be 0.252225" for this set which exceeds the Engineering high limit at 0.251500". All twenty-nine (29) holes were oversize and are contributors to the oversized accumulative average. The Individual Computer Printout, a history of the measurement features of each hole, is incorporated in this report. Paragraph III discusses the characteristics associated with this series of holes.

* DRILL METHOD CODING: H-2 = Hand-held drill and ream. Hand-held air powered drill driving a double-margin piloted tip. Hand-held, air powered special piloted reamer.

C. The Computer Statistical Printout provides clues traceable to the following for the production of these holes:

1. Custom major assembly fixturing ensures structure alignment and positioning reliability.

2. Hand-held, air powered drill method and accessories are adequate to the production of good quality preliminary holes in preparation for final reaming.

3. Hand-held, air powered drill motor driving a special reamer produces good quality final holes. An incorrect reamer was used on these holes resulting in a complete series of oversized holes.

4. The installed structural stainless steel hinge was used as the "lead-in" for the drilling and reaming operations. Use of the oversize reamer <u>enlarged</u> the lead-in hole on the hinge for this series of holes.

5. Planning is adequate to direct manufacturing and inspection operational requirements. Close tolerance holes are inspected by sampling per planning direction.

6. Morale among production personnel is high. The attributes of pride and craftsmanship are evident in the quality of work produced. The technician responsible for this series of holes was <u>markedly concerned</u> at the error which resulted in oversized holes.

III. <u>CHARACTERISTICS:</u>

A. Hole Size: a. Reference "Executive Summary by Data Lot". 580 measurements were accrued for this series of twenty-nine (29) holes. The arithmetical average for the set is 0.252225" and hole finish was scored by the stainless steel chip migration into the aluminum structure during oversize reaming. All twenty-nine (29) holes of the set exhibit out of tolerance measurements as evidenced by their individual computer statistical printout.

b. Five holes, identified #3, 12, 19, 20 and #21, were the only holes whose hinge (stainless steel) portion of the hole remained within the 0.251500" high limit tolerance. The aluminum structure following the hinge lead-in was oversize in all holes.

c. All other holes in this set were oversize at the hinge lead-in and follow-on aluminum structure.

d. The side-load effect induced via operator instability on the drill power head and short engagement length of the steel hinge lead-in hole is evident in measurement results. Examples are:

Hole #1, side loading at 0° and 135° axes are predominant.

Hole #3, side loading at 45° and 90° axes are predominant.

Hole #20, side loading at the 0° and 135° axes are predominant.

There are numerous other holes exhibiting similar characteristics at various axes.

e. On basic hole size, each hole is an individual oversize case study whose measurement profile depends on the "chip" and side-load influence induced via the reaming operation.

B. Ovality:

a. The greatest ovality of the set occurred at Hole #15, Level #1 and was recorded at 0.004569". The consequence of hole ovality is the result of excessive side loads at the 0° and 135° axes of the hole.

b. Ovality throughout this set of holes was affected by the side loads induced by the drill operator. The condition was significant since most of the holes in this series exceeded the Engineering tolerance range.

C. Perpendicularity: Owing to the basic contour of the hinge, fasteners were installed in several holes and head gap was inspected for perpendicularity of the hole. In addition, the concentricity of the countersink to the hole shank was visually checked at 3X magnification. The holes were perpendicular to the skin contour.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: Occasional, as evidenced by profile analyses per Hole #5 and #6 examples.

F. Bellmouthing: Generally evident as "taper" indicated by profile analyses. This characteristic was precipitated as a result of hand tooling and operator instability. Remedial dispositioning action will address this series of holes.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes were scored as a result of the steel hinge chip gouging the sidewall of the aluminum structure. Remedial action planned for dispositioning affected holes.

H. Burrs: This set of holes, drilled through a stacked arrangement of hardware members was deburred satisfactorily in the normal process plan work instructions but is subject to re-evaluation owing to the oversized condition of the set.

I. Surface Finish: All holes of this set exhibited a surface marred by chip scores. Optical Surface Comparator was used in this inspection. Finish approximates "125 AA" except for scores and areas where the gray sealant impinged onto the hole sidewalls.

DRILL METHOD Q-1

RANKING NUMBER 84 *

HOLE SIZE: 0.250"/0.254"

I. OVERVIEW:

A. This set of production holes feature drilling and reaming of the Carry Thru, Front Spar Assembly. The structure is an aluminum stack-up approximately .500" thick. The subject hole is sized by Engineering at 0.250"/0.254".

II. SUMMARY:

A. Twenty-nine (29) holes were available in this structure for inspection. The method of production utilized a custom built assembly fixture to assure hole location. Holes were drilled by Quackenbush air powered drill with automatic feed and retract. Drilling was followed by hand-held air feed drill motor powering a 0.2500" reamer. Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose arithmetical average is 0.252158" for the set of twenty-nine (29) holes. This figure represents an excellent margin when considering the Engineering tolerance limits at 0.250"/0.254". However, the Individual Hole Computer Printout reveals an operator induced characteristic in several holes tending toward hole quality degradation and is worthy of comment to reverse an adverse trend. Details on hole quality are discussed in paragraph III.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixture ensures interchangeability and location reliability.

2. Quackenbush air powered drill used for drilling with accessory drill plate integral to the fixture.

3. Hand-held air powered drill motor driving a 0.2500" reamer to obtain final sizing of the finished holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. CHARACTERISTICS:

A. Hole Size: a. Reference "Executive Summary" for this set. 580

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand-held Air Power Reamer.

Quackenbush, hand-held air driven drill using a reamer for final hole sizing.

measurements were accrued for this series of holes. The Arithmetical Average for the set is 0.252158".

b. The predominant detrimental characteristic to hole quality is "side loading" induced via operator weight moment arm on the drill during reaming and/or drill motor alone weight moment arm. Virtually all of the holes reveal their exit planes to be larger than the start plane into the structure. In addition, the Individual Hole Profiles disclose generally the 90° and 135° axes exhibiting the largest of the plane measurements. Again, this is operator and/or weight loading in predominantly one direction.

c. Eight (8) holes disclosed measurements in excess of the drawing tolerance allowable. These holes are Hole #2, #7,#16,#17,#19,#20,#27 and #28.

   1. All of the above listed holes exhibit the exit plane ovality induced by weight side loading.

   2. Hole #7 <u>oversize</u> dimension (0.255100") occurred at plane level #3 which is an interface between two (2) material laminates of the hardware stack-up. It is suggested to be a "chip scar" of negligible consequence since it occurs only once, is at only one (1) orientation (45°) in the measurement plane and disappears at the next deeper measurement plane in the hole.

   3. Hole #17 revealed its oversize condition to be at the <u>entrance</u> plane of the hole. This hole exhibited a rather generous chamfer from deburring of the hole and its consequence on hole degradation also was discounted since it eliminiated itself at the next deeper measurement plane.

   4. Hole #20, the worst of the set, is oversize over practically its entire length. Wobble via the operator and reamer stalling are the most probable causes for this oversized hole. Hole #20 exhibited the largest reading of the entire set at 0.256776"which occurred at its exit plane.

B. Ovality: Hole #23 exhibited the greatest ovality of the set with a reading of 0.004569" at the 45°-135° axes. As previously stated, this phenomenon occurred at the exit plane of the hole and is the result of operator/drill motor side loading via the weight moment arm. The influence of side loads is apparent in the ovality measurement of the individual hole computer printouts.

C. Perpendicularity: All Holes within this set were normal to the longitudinal axis of the hole with regard to the structure station plane face. Perpendicularity was verified to be zero degrees (0°) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: General tendency toward "taper" as evidenced by profile analyses but within the allowable Engineering tolerance criterion except for the holes noted in Item III. A.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through a stacked arrangement of fuselage station frames, doubler and fitting were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-2

RANKING NUMBER 85 *

HOLE SIZE: 0.3125"/0.3165"

I. OVERVIEW:

A. This set of production holes features drilling and reaming of a Vertical Fin Attach Bulkhead. The structure is an aluminum stack-up of varying thickness owing to the differences in the adapters. The subject hole is sized by Engineering at 0.3125"/0.3165".

II. SUMMARY:

A. Twenty (20) holes only were available in this structure for survey. The method of production utilized custom fixturing to assure hole location. Holes were drilled by hand-held air powered drill motor and reamed via hand-held air powered drill motor driving a hole final sizing reamer. Inspection measurements were obtained by the Survey Team using a "thru-hole" air probe.

B. These holes disclose a measurement distribution whose arithmetical average is 0.314315" for the set of twenty (20) holes.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes.

1. Custom fixturing ensures interchangeability and location reliability.

2. Hand-held air powered drill and fixture mounted drill plate for preliminary holes.

3. Hand-held air powered drill motor with fixture coupled reamer guide bushings for final hole reaming.

* DRILL METHOD CODING: H-2 = Hand-held Drill and Ream.

Hand-held, air driven & custom fixtured for drilling; hand-held air driven drill driving a reamer for final hole sizing.

II. C. (Continued)

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary" for this set. 480 measurements were recorded for this series of twenty (20) holes with the average reading, 0.314315", residing at the mid-point range of the Engineering tolerance. The Individual Histograms do not reflect a conclusive crowding of measurements. Measurements randomly exhibit themselves from clusters, to virtual full utilization of the tolerance range, suggesting "rattle space" between the drill/reamer and guide bushing coupled with operator side loading as causes for the measurement pattern. "Spikes" in the hole profiles favoring one (1) or adjacent axes suggest side load influence resulting in oversize dimensions. The fact that these holes per fixture positioning were drilled and reamed from nearly vertical (as opposed to horizontal per other sets) minimized the severity of the side load "spikes".

b. Holes #4, #6, #8 and #19 favor the operator side load affect resulting in oversize, oval holes.

c. Holes #2 and #12 likewise suggest side loads. Reference to 45^{o} axis group of measurements per the Individual Hole Profile reveals dimensions <u>immediately</u> above the oversize dimensions and along the same axis <u>to be approaching</u> an oversize condition. As depth was increased, the measurements went out of tolerance. Hole #12 follows the same pattern except along the 135^{o} axis.

III. A. (Continued)

d. Hole #15 is similar. Reference the 90^{o} axis of measurements in conjunction with the oversize condition.

B. Ovality: Hole #15 exhibited the greatest ovality of the set with a reading of 0.003922" at the 0^{o}-90^{o} axes at level 2, and 0.003414" at the 45^{o}-135^{o} axes at level 6. The influence of side loads is apparent in the ovality measurement of the individual hole computer printouts.

C. Perpendicularity: All Holes within this set were normal to the longitudinal axis of the hole with regard to the structure station plane face. Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: General tendency toward "taper" as evidenced by profile analyses but within the allowable Engineering tolerance criterion except for the holes noted in Item III. A.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

III. (Continued)

H. Burrs: This set of holes, drilled and reamed through a stacked arrangement of fuselage station bulkhead and adapter pads were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-3

RANKING NUMBER 86 *

HOLE SIZE: 0.6245"/0.6255"

I. OVERVIEW:

A. The structure is a steel to aluminum stack-up approximately 1.20" thick and the subject hole is sized by Engineering at 0.6245"/0.6255" after finish reaming.

II. SUMMARY:

A. Eight (8) holes were available in this structure for survey inspection. The sequence of production directed preliminary reaming of the holes to prepare them for cold working; Cold work split sleeve and mandrel expansion of the holes; Hand reaming to the final size for fastener installation. Hole expansion was accomplished via air powered tooling and the reaming operations by hand held air powered drill motors driving piloted tip reamers.

* DRILL METHOD CODING: H-3 = Hand Held Drilling; Cold Worked Hand Reaming

All of the holes in this set exceed the high limit tolerance of 0.6255" and are therefore candidates for Material Review Board action and/or rework to the next larger fastener size permitted by the Modification Program.

B. Reference Executive Summary for Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.627665" for the set of eight (8) holes. This value exceeds the high limit of the tolerance and is therefore unacceptable. Considering the operation as a Field Task, without assist/stabilizing tooling, the tolerance does not appear realistic. Specific discussion on the geometric characteristics of the holes are discussed at paragraph III along with rationale disclosures for most probable causes for the oversize conditon on this series of holes.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following:

1. Hand-held air powered drill motors for final reaming operations.

   NOTE: Reamer is a cobalt four fluted long shank piloted tip reamer sized at 0.6150" (tip) and 0.6245" (shank).

2. Lack of assist tooling to stabilize reamer and powerhead.

3. Affect of reaming the combination of steel and aluminum in the assembly stack is apparent.

[. <u>CHARACTERISTICS</u>:

A. Hole Size: 576 data measurements were accrued from the eight (8) holes comprising this set. Reference, Executive Summary by Data Lot discloses an arithmetical average of 0.627665" for the set which <u>exceeds</u> the high limit of the Engineering tolerance. This set has an insufficient quantity of specimens to draw solid statistical analyses; However, the measurement data taken at seventy-two locations within each holes does provide realistic hole profile replicas and strikingly pinpoints most probable cause for failure to meet the tolerance criterion.

Reference Individual Hole Computer Printouts. The following geometric characteristics are apparent in the data which is <u>common</u> to all holes of this set.

1 - <u>All</u> of the steel fittings (the first four planes of measurements), are oversize.

2 - <u>All</u> of the holes reveal a <u>chain-lobing</u> oversize condition at various depths within each hole.

The above conditions point to the following as the most probable cause for the features existing in this series of holes.

1 - The technician performing the reaming operation with a long shank piloted reamer is not stable during the duty cycle of reaming.

2 - The steel fitting acting as a guide bushing during the reaming cycle resists operator side loads and in turn acts as a pivot which creates the lobing chain inside the hole.

3 - The chain most probably results from variations in the force an operator induces during the reaming cycle since he is pushing up from the underside of the wing. His slight shifts in body position and variations in thrust (tiring of the arms) are transmitted through the pivot point (steel fitting) and result in a lobe inside the hole.

4 - The several variations that create the lobes in turn induce excessive reamer engagement on the pivot resulting in its oversize condition.

5 - Two (2) aircraft were involved in this series of holes. <u>Separate</u> crews performed the <u>same</u> tasks, with <u>similar</u> results; Therefore, further study and methods evaluation seem appropos.

Information: Data disclosure on high/low measurements of the holes and maximum oversize conditions.

Hole #	High	Low	Maximum Oversize
1	0.629741"	0.626526"	0.004241"
2	0.630216"	0.626379"	0.004716"
3	0.630034"	0.627147"	0.004534"
4	0.629897"	0.627250"	0.004397"

Hole #	High	Low	Maximum Oversize
5	0.628914"	0.625862"	0.003414"
6	0.627388"	0.625517"	0.001888"
7	0.626474"	0.625569"	0.000974"
8	0.627302"	0.625172"	0.001802"

B. Ovality: Maximum recorded ovality within the set occurred at Hole #4 and discloses a value of 0.002647" or the 0° - 90° axes at level 2. Ovality at this hole exceeded the Engineering tolerance criterion and is the product of the bellmouth feature in the steel member of the assembly stack.

Holes #1 and #2 also exceeded the Engineering tolerance criterion by exhibiting values of 0.001190" and 0.001509" respectively. Both occurred at level 17 on their 0° - 90° axes. The lobing feature is discussed at length in paragraph III.A.1 thru III.A.4.

C. Perpendicularity: Adjacent installed fasteners would not permit inspection via the Angle/Azimuth Gaging Device; therefore verification of perpendicularity was accomplished via inspection of the head to faying surface contact of other fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion.

D. Straightness: Straightness is within Engineering design tolerances as indicated by profile analyses.

E. Barrelling: All holes of this set are barrelled in series, manifesting the feature as links in a chain. The characteristic and cause are discussed in paragraph III.A.1 thru III.A.4.

F. Bellmouthing: All holes are bellmouthed as referenced in the pivot characteristic. Refer to narrative at paragraph III.A.1 thru III.A.4.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited fair interior wall texture. There was shallow angle rifling in most of the holes exceeding the 125 AA machine finish. Inspection was performed with Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: There was no evidence of burrs in the stack-up of materials in the assembly.

I. Surface Finish: All holes of this set exhibited a surface finish of 125 AA except for rifling. Optical surface comparator was used in this inspection. Surface was generally smooth except for rifling.

DRILL METHOD S-1

RANKING NUMBER 87 *

HOLE SIZE: 0.3125"/0.3175"

I. OVERVIEW:

A. This set of production holes features "one-shot" drilling and countersinking of the Pylon Assembly, Fuel Tank.

The structure is an assembly of heavy aluminum skin and a steel pylon forging whose thickness is approximately 0.40" irrespective of the skin. The subject hole is sized by Engineering at 0.3125"/0.3175" for installation of C7984-5 Flush Head High Shear Bolts located at Pylon Stations 50.63 and 75.59.

B. The structure being surveyed is presently being reviewed and evaluated for process and tooling revision from Winslow (Spacematic) drilling and attendant tooling, to Quakenbush drilling/reaming and complementary fixturing. High maintenance on the Winslow power unit, frequent drill/reamer breakage and resultant hole quality degradation are factors steering the changeover process.

II. SUMMARY:

A Twelve (12) holes were surveyed from one (1) available assembly on the factory line. A very minute shift of the outer skin on the right hand side of the unit (Clecoed to the forging) resulted in interference which prevented entry of the "thru-hole" air probe; thus, only twelve (12) holes in the pattern were surveyed. The method of production utilized the Winslow air driven power head for drilling and countersinking. Spray-mist coolant integrally coupled to the powerhead provided adequate cooling during the duty cycle of the drill. Frequent drill stalls were noted during the drilling process of another pattern of holes and of different size on this unit. The operation was stopped because of breakage of the drill bit during its duty cycle and becoming lodged in the steel forging. The event was the third breakage incident noted on this production unit.

* DRILL METHOD CODING: S-1 = Spacematic, One-shot, no reaming. Winslow, air powered drill & accessory tooling producing "one-shot" full sized holes.

II. (Continued)

B. Reference Executive Summary by Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.316165". This is an exceptionally high value brought about by a chronic chip load build up which resulted in two-thirds of the holes of this set exceeding the high limit of the Engineering tolerance. Specific discussion on the geometric characteristics of all holes are discussed at paragraph III.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixturing ensures interchangeability and location reliability of the basic structure.

2. Winslow, air powered drill and accessory tooling producing "one-shot" full sized holes at assembly is plagued with excessive maintenance at this work station.

3. "One-shot" full sized drilling in the steel forging appears to be an overload for Winslow operations.

4. Planning is very good, providing adequate work instructions and definition of inspection requirements. Plug "Go"/"No-Go" gaging is employed in hole inspection.

5. Visual aids (illustrated assembly breakdown by Bulkhead Fuselage Station) is an invaluable asset providing a visual reference of the overall assembly concept to line personnel.

III. <u>CHARACTERISTICS</u>:

A. Hole Size: 240 data entries were accrued for the series of twelve (12) holes. The arithmetical average for the set is 0.316165". This average is exceptionally high and brought about by the fact that <u>all</u> of the holes in this set are tapered and approach and/or exceed the high limit tolerance 0.3175" established by Engineering.

III. A. (Continued)

1. Eight (8) holes, identified #3, #5,#6,#7,#8,#10,#11 and #12 are oversize. Chip build-up load results in severe taper and/or bellmouth of the holes. Cause of the problem is divulged in narrative per II.A. and II.B.

2. Hole #12, the worst hole of the set, is the result of drill bit breaking inside the hole. The problem of full size drilling in steel via Winslow method is known and being addressed for method change and tool redesign.

3. The Histograms, both Summary by Lot and Individual, reflect a utilization of the entire tolerance band owing to the taper built into the hole by chip loading. The start of drilling yields the smallest diametrical records and increase as depth and chip load increase.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #12 and recorded at 0.002810" at Level #5 on the 0^{o}-90^{o} axes. Ovality in this hole results from drill breakage in the hole during its duty cycle.

Ovality in this set was plagued by drill stalling and chip loading resulting in oval holes. The ovality problems in this set are known and are being addressed via process and tool redesign.

C. Perpendicularity: Holes were checked by gaging with a 10X magnification Azimuth/Angle Gaging Device. Holes were normal (90^{o}) to the longitudinal axis of the holes.

III. (Continued)

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: None existent as evidenced by profile analyses.

F. Bellmouthing: This characteristic is the most predominant geometric feature of the set. Bellmouthing and/or taper has been defined on affected holes of this set in the narrative per III.A.1 through III.A.3.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of parts exhibited a fair interior hole sidewall texture. There were prolific shallow angle rifling perceptible on several holes when inspected by Sight Pipes at 3X magnification. There were occasional chatter marks but no scoring in these holes.

H. Burrs: This set of holes, drilled and reamed at assembly, were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "125 AA". Optical Surface Comparator was used in this inspection.

DRILL METHOD Q-1

RANKING NUMBER 88 *

HOLE SIZE: 0.250"/0.254"

I. OVERVIEW:

This set is a split series taken from two (2) structural assemblies as follows to complete a twenty-nine (29) hole sample.

A. This series of eight (8) production holes feature drilling and reaming of a Carry Thru, Front Spar Assembly. The structure is an aluminum and steel stack-up approximately .500" thick. The subject hole is sized by Engineering at 0.250"/0.254".

B. This series of twenty-one (21) production holes feature drilling and reaming of a Carry Thru, Rear Spar Assembly. The structure is an aluminum stack-up approximately .500" thick. The subject hole is sized by Engineering at 0.250"/0.254".

II. SUMMARY:

A. Twenty-nine (29) holes were available in the above structures for inspection. The method of production utilized a custom built assembly fixture to assure hole location. Holes were drilled by Quackenbush air powered drill with automatic feed and retract. Drilling was followed by hand-held air feed drill motor powering a 0.2500" reamer. Inspection measurements were obtained by "thru-hole" air probe.

B. These holes disclose a measurement distribution whose arithmetical average is 0.253110" for the set of twenty-nine (29) holes. Also, prior to performing the hole measurements, the area crew chief identified holes #27, #28 and #29 as rejected specimens and requested a profile readout to confirm his knowledge. Results for these holes are recorded herein via the above identification.

Individual Hole Computer Printout reveals an operator induced side load characteristic in most holes tending toward hole quality degradation and is worthy of comment to reverse an adverse trend. Details on hole quality are discussed in paragraph III.

C. The computer data Statistical Printout for this series of holes provides composite clues traceable to the following for the production of these holes:

1. Custom designed fixture ensures interchangeability and location reliability.

* DRILL METHOD CODING: Q-1 = Quackenbush, Hand-held, Air Power Reamer.

Quackenbush, air powered & custom fixtured for drilling; hand-held air driven drill driving a reamer for final hole sizing.

2. Quackenbush air powered drill used for drilling with accessory drill plate integral to the fixture.

3. Hand-held air powered drill motor driving a 0.2500" reamer to obtain final sizing of the finished holes.

4. Planning is adequate to ensure model and serial number traceability for assembly but is too abbreviated to provide other than "Go"/"No-Go" gaging acceptance on holes.

III. <u>CHARACTERISTICS</u>:

A. Hole Size:

a. Reference "Executive Summary" for this set. 580 measurements were accrued for the total lot of twenty-nine (29) holes. The Arithmetical average for the set is 0.252110".

b. The first eight (8) holes of this set taken from the Front Spar Carry Thru whose stack-up is approximately .500" thick included the steel fitting at the last laminate of the stack. This series of holes is considerably <u>better</u> in quality than the twenty-one (21) holes per paragraph I. B. which were drilled and reamed through an <u>all aluminum</u> stack-up on the Rear Spar Carry Thru assembly. Characteristics for the holes identified #1 thru #8 are:

1. These holes were fixture drilled and reamed by hand slightly <u>undersize</u> since the area inspector's "go-gage" would not enter the holes. The technician re-reamed the holes using a 0.2500" reamer and on the second inspection the holes accepted the gage. The Hole Survey Team followed with measurement results as follows.

2. The Arithmetical Average is 0.251495" for the series of eight holes in the Front Spar Carry Thru. This average is considerably better than 0.253110" which is the overall average for the twenty-nine (29) hole aggregate set. The undersize first reaming operation followed by a second, very light cut, is the most probable reason for these holes more closely crowding the low limit of the tolerance (0.250000").

3. <u>All</u> of the Front Spar Carry Thru holes met the Engineering tolerances without exception.

4. The predominant detrimental characteristic to hole quality is "side loading" induced via operator weight moment arm on the drill during reaming. Virtually all of the holes reveal their exit planes to be larger than the start plane into the structure. In addition, the Individual Hole Profiles disclose the plane measurements to be "cone shaped", "tapered" or "bellmouthed". Dwell time in the steel, break-out and operator side load most likely is the cause for "bellmouthing" the exit planes of the holes. "Bellmouthing" is generally less than 0.001" except for Hole #9 which is 0.002" owing to its last plane of measurements.

5. Individual Hole Histograms for the Front Spar Carry Thru holes also disclose a dimensional population crowding the 0.251000" plateau, which is excellent for these holes and probably is a function of two (2) reaming passes. These holes also are of better quality on "roundness" since their measurement spread is less than 0.001".

6. The remainder of the hole characteristics are common for the entire set of twenty-nine (29) holes and are discussed as a composite beginning at Item III. B. and continuing through Item III. I.

c. The twenty-one (21) holes representative of the Rear Spar Carry Thru Assembly were similar but slightly <u>larger</u> in size than the holes discussed in paragraph III.A. b. above.

The predominant detrimental characteristic to hole quality for this series of twenty-one (21) holes is "side loading" induced via operator weight moment arm on the drill during reaming and/or drill motor alone weight moment arm. Virtually all of the holes reveal their exit planes to be larger than the start plane into the structure.

d. Seventeen (17) holes disclosed measurements in excess of the drawing tolerance. These holes are #9; #11 throught #13; #15 through #17; and #20 through #29.

1. Hole #9 exhibiting a "double bellmouth" suggests wobble and operator "side load" since the condition exists at the entrance and exit planes and down the sidewall of the hole at its 0° and 135° axes.

2. Holes #11,#15,#16,#21,#22,#24,#25,#27 and #28 exhibit "side load" characteristics or oversize since the measurements trace one (1) or two (2) adjacent axes down through the holes.

3. Hole #12 revealed its oversize condition to be at the <u>entrance</u> plane of the hole. Hole degradation was discounted since it eliminated itself at the next deeper measurement plane. Deburring chamfer was the most probable cause for the oversize "lead-in" plane.

4. Holes #17,#20 and #26 recorded only one (1) measurement out of tolerance. They all occurred at the exit planes of the drill/reamer. Most probable cause for this"spike" is uneven break-out chip load. Hole degradation was discounted as extremely negligible.

5. Hole #23 exhibits three (3) oversize readings at plane level #4. The condition is suggested as "chip scar" since it occurs at one (1) plane and is tapered in depth as it progresses around the plane axis. Hole degradation is extremely negligible and was discounted per analysis on the noted condition.

6. Holes #13 and #29 are the most severely oversized holes of the entire set and are oversize throughout their entire length. Highest reading per hole was recorded at 0.256724" and 0.256448" respectively. The spikes per Profile Analyses are random and at various levels for both holes. Drill/reamer stall coupled with operator side loading is the most probable cause for the oversize condition of these holes. Stall is suspected since there are so many "spikes" in the holes and at varying axes and levels.

B. Ovality: Hole #15 exhibited the greatest ovality of the set with a reading of 0.003586" at the 45°-135° axes at level 4. As previously stated, this phenomenon is

the result of operator/drill motor side loading via the weight moment arm. The influence of side loads is apparent in the ovality measurement of the individual hole computer printouts.

C. Perpendicularity: All Holes within this set were normal to the longitudinal axis of the hole with regard to the structure station plane face. Perpendicularity was verified to be zero degrees (0^{o}) when measured with the 10X magnification Azimuth/Angle Gaging Device.

D. Straightness: Straightness is within Engineering design tolerance as indicated by the profile analyses.

E. Barrelling: None evident as indicated by the profile analyses.

F. Bellmouthing: General tendency toward "taper" as evidenced by profile analyses but within the allowable Engineering tolerance criterion except for the holes noted in Item III.A.

G. Hole Texture: Rifling, Scratches, Chatter marks. This set of holes exhibited a very good interior wall texture. There was only an occasional very shallow angle rifling when inspected by Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: This set of holes, drilled and reamed through a stacked arrangement of fuselage station frames, doubler and fitting were satisfactorily deburred in the normal process plan work instructions.

I. Surface Finish: All holes of this set exhibited a surface finish of "100 AA" or better. Optical Surface Comparator was used in this inspection. Surface was smooth and shiny.

DRILL METHOD H-3

RANKING NUMBER 89 *

HOLE SIZE: 0.4375"/0.440"

I. OVERVIEW:

A. This series of specimens feature preliminary reaming of holes to performing a cold work expansion operation. The holes are located on the Fuselage to Wing Attach Fitting. The structure is a steel to aluminum stack-up approximately 0.90" thick and the subject hole is sized by Process Criterion at 0.4375"/0.440"; 0.0030" over the reamer size of 0.4375".

II. SUMMARY:

A. Six (6) holes were available in this structure for survey inspection. The sequence of production directed preliminary reaming of the holes to prepare them for cold working. A hand-held air powered drill motor driving a piloted tip reamer was employed to accomplish the task. No other supplementary tooling was provided for this operation.

B. Reference Executive Summary for Data Lot. This set discloses a measurement distribution whose arithmetical average is 0.440137" for the set of six (6) holes. This value slightly above the high limit of the tolerance is a result of slight barrelling in Holes #1 thru #4 and a significant crescent defect in Holes #5 and 6.

C. The Computer Statistical Printout for this series of holes provides composite clues traceable to the following:

1. Hand-held air powered drill motors for final reaming operations.

   NOTE: Reamer is a six fluted long shank piloted tip reamer sized at 0.430" (tip) and 0.4375" (shank).

* DRILL METHOD CODING: H-3 = Hand Held Drilling; Cold Worked Hand-Held Reaming

2. Lack of assist tooling to stabilize the reaming operation.

3. Affect of reaming the combination of steel and aluminum in the assembly stack is evident.

III. CHARACTERISTICS:

A. Hole Size: 336 data measurements were accrued for the six (6) holes comprising this set. Reference, Executive Summary by Data Lot, discloses an arithmetical average of 0.440137" for the set, slightly over the Engineering High Limit Criterion. This set has an insufficient quantity of specimens to draw solid statistical analyses; however, the measurement data taken at fifty-two (52) and sixty (60) locations within each hole does provide realistic hole profile replicas.

1. Hole #1. Reference Individual Hole Computer Printout. This hole has a slight series of barrelled features at various depths inside the hole. In addition, the data for the 0° and 135° axes reveal a measurement series consistently larger than the 45° and 90° axes and are a result of the gravity vector (0°) and technical instability during the duty cycle of the reaming operation.

   Pivoting on the steel fitting results in the lobing feature (barrelling) and weight of the drill power unit tends to provide the ingredient necessary for ovality at the 0° axis.

2. Hole #2 is oversize over its entire length and also has the lobing (barrelled) features at varying depths along the hole. Pivoting on the steel fitting again in accessed the cause for the barrelling features in this hole.

3. Hole #3 features the same characteristics as Holes #1 and 2 except that all measurements remain within the Engineering tolerance.

4. Hole #4 is slightly over tolerance in the hole immediately forward of the steel fitting. It has a very slight barrelled feature at the interface of the steel fitting to aluminum members following it in the assembly stack. In addition, there is a spike in the data at plane level 4. This spike, at <u>all</u> axes, has been discounted as a defect in the hole analysis. In reality, plane level 4 is an interface gap between the steel fitting and the aluminum shim following it; thus, the barrelled feature encompasses the forward portion of the fitting, the aluminum shim and slightly into the aft side of the spar cap in the assembly stack. Steel chip impingement into the aluminum members of the stack is the most probable cause for the slightly barrelled characteristic.

   The maximum measurement in Hole #4 is 0.441595" at plane level 5 on its 0^{o} axis. 0.441922" at plane level #4 is void since it is the interface discussed above. The 0^{o} axis of this hole is the gravity vector with regard to reaming and reflects the side load as a result. The measurements along this axis are slightly larger than those for the remaining axes.

5. Hole #5 and 6 are unique. Due to a shift in the shim, a double hole results. Inspection by Sight Pipe at 3X magnification revealed complete absence of metal over a quadrant of approximately one third (1/3) of the hole and it is evident in the data at plane levels 5 and 6.

   In addition, on the forward side of the assembly stack there was a large section of material missing in these holes as received from the manufacturer. In both cases, the affected area was crescent shaped and covered approximately one quarter (1/4) of the hole. Refer to sketch for estimated details. The flaw area was too large and beyond the measurement capability of air gaging.

B. Ovality: Maximum recorded ovality within the set occurred at Hole #1 and discloses a value of 0.003397" on the 0^{o} - 90^{o} axes at plane level 1. Ovality at this hole exceeded the Engineering tolerance criterion and is the product of the ovality feature in the steel member of the assembly stack resulting from the gravity vector direction in regard to the reaming direction.

Holes #5 and 6 were discounted via analysis for ovality because of the crescent shaped defect discussed in paragraph III.A.5.

C. Perpendicularity: Adjacent installed fasteners would not permit inspection via the Angle/Azimuth Gaging Device; therefore, verification of perpendicularity was accomplished via inspection of the head to faying surface contact of other fasteners in the structure. The holes were normal to the longitudinal axis of the holes and acceptable to established Engineering criterion.

D. Straightness: Straightness is within Engineering design tolerance as indicated by profile analyses.

E. Barrelling: Slight barrelling is a chain feature in all holes as described in the narrative at Par. III.A.1 thru III.A.5.

F. Bellmouthing: Rejected in Hole #2, refer to narrative at III.A.2.

G. Hole Texture: Rifling, Scratches, Chatter Marks. This set of holes exhibited acceptable interior wall texture. There was only an occasional very shallow angle rifling in the holes that did not exceed the 125 AA machine finish. Inspection was performed with Sight Pipes at 3X magnification. There were no chatter marks nor vertical scoring in these holes.

H. Burrs: There was nc evidence of burrs in the stack-up of materials in the assembly.

I. Surface Finish: All holes of this set exhibited a surface finish of 125 AA or better. Optical surface comparator was used in this inspection. Surface was smooth and shiny in all holes except for the rifling lines described at item G above.

*U.S.Government Printing Office: 1980 — 787-002/224